

Preface

The idea of the book entitled “**Physical Chemistry: SET PYQ’s**” was born because of the lack of any comprehensive book covering all the aspects of various entry level chemistry competitive examinations in particular conducted by CSIR, GATE, TIFR State and National Eligibility Test, but not limited to.

This book covers all PYQ’s with topic wise sorted question and solution

1. Quantum Chemistry,
2. Molecular Spectroscopy,
3. Group Theory,
4. Chemical Thermodynamics,
5. Statistical Thermodynamics,
6. Electrochemistry,
7. Chemical Kinetics,
8. Colloidal and Surface Chemistry,
9. Solid State,
10. Polymer Chemistry.

The ultimate purpose of this book is to equip the reader with brainstorming challenges and solution for organic chemistry and applied aspect examinations. It contains predigested information on the entire academic subject of organic chemistry for good understanding, assimilation, self-evaluation, and reproducibility. Although we have made every effort to make the book error free, we are under no illusion. We welcome comments, criticism and suggestions from the readers to evolve the contents.

Acknowledgement

First of all I would like to thank our entire students at Institute for advanced Studies (IFAS), who have helped us to learn and practice both the art and science of chemistry. We would like to thank Er. Radheshyam Choudhary, Founding CEO, IfAS Edutech Pvt. Ltd. for being a continuous source of inspiration through his positive strokes.

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INDEX
SET PHYSICAL CHEMISTRY

CHAPTER NO.	CHAPTER NAME	PAGE NO.
1	QUANTUM CHEMISTRY	1
2	MOLECULAR SPECTROSCOPY	47
3	GROUP THEORY	78
4	CHEMICAL THERMODYNAMICS	103
5	STATISTICAL THERMODYNAMICS	143
6	ELECTRO CHEMISTRY	159
7	CHEMICAL KINETICS	193
8	COLLIDAL & SURFACE CHEMISTRY	236
9	SOLID STATE	253
10	POLYMER CHEMISTRY	271

PREVIOUS YEAR EXAM QUESTION

CHHATTISGRAH SET

[CG-SET 2017: 2 Mark]

1. If $\phi(\varphi) = Ne^{im\varphi}$ with $0 \leq \varphi \leq 2\pi$ the normalization constant N equals to:

- (A) π (B) $\frac{1}{\pi^2}$
(C) $\left(\frac{1}{\pi}\right)^{1/2}$ (D) $\frac{1}{2\pi}$

[CG-SET 2017: 2 Mark]

2. The commutator of $\left[\hat{x}, \hat{p}_x\right]$ is:

$\left(\hbar = \frac{h}{2\pi}, h \text{ Plancks constant}\right)$

- (A) zero (B) $i\hbar$
(C) 1 (D) $\hbar$

GUJARAT SET

1. Mathematical expression for Hamiltonian operator, $\hat{H}$ is

- (A) $+\frac{\hbar^2}{2m}\nabla^2 - V$ (B) $+\frac{\hbar^2}{2m}\nabla^2 + V$
(C) $-\frac{\hbar^2}{2m}\nabla^2 - V$ (D) $-\frac{\hbar^2}{2m}\nabla^2 + V$

2. The magnitude of the angular momentum ($\vec{L}$) of an electron that couples the 3d orbital is

- (A) $\sqrt{2} \frac{\hbar}{2\pi}$ (B) $3\sqrt{2} \frac{\hbar}{2\pi}$
(C) $\sqrt{6} \frac{\hbar}{2\pi}$ (D) $\frac{\hbar}{2\pi}$

3. According to the huckel's theory for conjugated π - electron system, the lowest π - M.O. energy value for cyclobutenyl system is

- (A) $\alpha - 2\beta$ (B) $\alpha + 2\beta$
(C) $\alpha + \beta$ (D) $\alpha - \beta$

4. The lowest energy molecular orbital for the allyl system is

- (A) $\frac{1}{\sqrt{2}}\chi_1 - \frac{1}{2}\chi_2 - \frac{1}{\sqrt{2}}\chi_3$

- (B) $\frac{1}{\sqrt{2}}\chi_1 - \frac{1}{\sqrt{3}}\chi_1 + \frac{1}{\sqrt{2}}\chi_1$
(C) $\frac{1}{\sqrt{3}}\chi_1 - \frac{1}{3}\chi_2 + \frac{1}{\sqrt{3}}\chi_3$
(D) $\frac{1}{\sqrt{3}}\chi_1 + \frac{1}{\sqrt{3}}\chi_2 + \frac{1}{\sqrt{3}}\chi_3$

[GJ-SET 2022]

5. According to Huckel's theory for conjugated x-electron system, the highest π - M.O. energy value for cyclopentadienyl system is

- (A) $\alpha - 2\beta$ (B) $\alpha + (2 \cos \omega)\beta$
(C) $\alpha + 2\beta$ (D) $\alpha - (2 \cos \omega)\beta$

[GJ-SET 2022]

6. The highest energy 7-molecular orbital for the cyclopropenyl system is

- (A) $\frac{1}{\sqrt{6}}2\chi_1 - \frac{1}{\sqrt{2}}\chi_2 - \frac{1}{\sqrt{6}}\chi_3$ (B) $\frac{1}{\sqrt{2}}\chi_1 - \frac{1}{2}\chi_2 + \frac{1}{2}\chi_3$
(C) $\frac{1}{\sqrt{3}}\chi_1 + \frac{1}{\sqrt{3}}\chi_2 + \frac{1}{\sqrt{3}}\chi_3$ (D) $\frac{1}{\sqrt{6}}\chi_2 - \frac{1}{\sqrt{6}}\chi_3$

[GJ-SET 2022]

7. The zero-point energy of a particle in a one-dimensional box with infinite height is

- (A) $E = \hbar^2/2ma^2$ (B) $E = \hbar^2/8ma$
(C) $E = \hbar^2/8a^2$ (D) $E = \hbar^2/8ma^2$

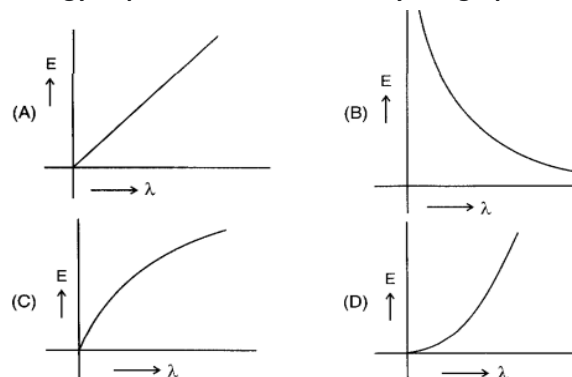
[GJ-SET 2023: Set 2]

8. One of the following is not an example of quantum mechanical tunneling phenomena

- (A) α - particle decay
(B) Inversion of ammonia
(C) Electron transfer reactions
(D) Combustion reactions

[GJ-SET 2023: Set 2]

9. Energy of photon is related to λ by the graph



[GJ-SET 2023: Set 2]

10. Which one of the following operators commute with each other?

i. $\hat{x}, \hat{p}_x$

ii. $\hat{p}_x, \hat{p}_x^2$

iii. $\hat{x}, \frac{\partial}{\partial x}$

iv. $\hat{x}, \frac{\partial^2}{\partial x^2}$

(A) i and iii

(B) i and iv

(C) ii and iv

(D) ii and iii

[GJ-SET 2023: Set 2]

11. In an excited state of a molecule, the uncertainty in position of an e⁻ is zero, then the uncertainty in momentum is given by

(A) $< \frac{\hbar}{2}$

(B) $< \frac{\hbar}{2}$

(C) 0 (zero)

(D) ∞ (infinity)

[GJ-SET 2023: Set 2]

12. The solution for a particle in 1D-box is given by $\Psi(x) = \frac{2}{L} \sin \frac{n\pi}{L} x$, where 'L' is the length of the box. Then the correct statement(s) are

(1) $\Psi(x)$ is a well behaved function(2) $\Psi(x)$ is not a normalised function(3) $\Psi(x)$ is an eigen function of Hamiltonian operator(4) $\Psi(x)$ is an eigen function of momentum operator

(A) 1, 2

(B) 2, 3

(C) 1, 3

(D) 2, 4

[GJ-SET 2023: Set 2]

13. The normalisation constant 'A' of the function $\phi_m(\phi) = A \cdot e^{im\phi}$, within the limits 0 to 2π is

(A) $\frac{1}{2\pi}$

(B) $\frac{1}{\sqrt{\pi}}$

(C) $\frac{1}{\sqrt{2\pi}}$

(D) 1

[GJ-SET 2023: Set 2]

14. In a linear conjugated system of length 'L', the 'N' number of move freely in a constant potential. The HOMO $\rightarrow$ LUMO transition in the molecular system involves the excitation of electron from

(A) $\frac{N}{2} \rightarrow \frac{N}{2} + 1$

(B) $\frac{N}{4} \rightarrow \frac{N}{4} + 1$

(C) $N \rightarrow N + 1$

(D) $\frac{N}{2} \rightarrow \frac{N}{2} + 1$

HIMACHAL PRADESH SET

[HP-SET 2014]

1. The wave function $\sin^{-1}$ is not acceptable, because it is:-
- (A) Not continuous
- (B) Not an eigen function of kinetic energy operator
- (C) Not differentiable
- (D) Not a single valued function

[HP-SET 2014]

2. The value of the commutator $[x, p_x^2]$, is given by:-
- (A) $2i$
- (B) $2i\hbar$
- (C) $2i\hbar x$
- (D) $2i\hbar p_x$

[HP-SET 2014]

3. The first order correction to energy for the ground state of a particle in a box due to perturbation λx is would be:-
- (A) $\lambda L/2$
- (B) λL
- (C) $2\lambda L$
- (D) 2

[HP-SET 2014]

4. The energy levels of cyclopropenyl cation are $\alpha + 2\beta$, $\alpha - \beta$ and $\alpha - \beta$. The delocalization energy of $C_3H_3^+$ is:-
- (A) 2β
- (B) 0
- (C) 3β
- (D) β

[HP-SET 2017]

5. The zero point energy of the harmonic oscillator is:-
- (A) $\hbar\omega$
- (B) zero
- (C) $\frac{1}{2}\hbar\omega$
- (D) $\frac{2}{3}\hbar\omega$

[HP-SET 2017]

6. The energy levels of the cyclobutadiene are $\alpha + 2\beta$, α , $\alpha - 2\beta$. The delocalization energy in this molecule is:-
- (A) 0
- (B) -4β
- (C) -8β
- (D) 4α

[HP-SET 2017]

7. If Δy and Δp_y are the uncertainties in the y coordinate and the y component of the momentum of the particle respectively, then according to the uncertainty principle $\Delta y \Delta p_y$ is ($\hbar = \frac{h}{2\pi}$ and h is a Planck's constant):-
- (A) $\geq \hbar$
- (B) $> \hbar/2$
- (C) $> \hbar$
- (D) $\geq \hbar/2$

[HP-SET 2017]

8. When hydrogen atom is placed in an electric field along the y-axis, the orbital that mixes most with the ground state 1s orbital is:-
- (A) 2s
- (B) $2p_x$
- (C) $2p_y$
- (D) $-2p_z$

[HP-SET 2018]

9. The separation between the adjacent energy levels of a particle in a one-dimensional box of length a is:
- (A) $n^2\hbar^2/8ma^2$
- (B) $(a/2)^{1/2}$
- (C) $(2n+1)\hbar^2/8ma^2$
- (D) $8ma^2/\hbar^2$

[HP-SET 2018]

10. The energy of photon associated with light of wavelength 200 nm is:
- (A) $99 \times 10^{-19} \text{ J}$
- (B) $0.9 \times 10^{-19} \text{ J}$
- (C) $9.9 \times 10^{-19} \text{ J}$
- (D) $9.0 \times 10^{-19} \text{ J}$

[HP-SET 2018]

11. If $e^{\alpha x}$ is an eigen function and d^n/dx^n is an operator, then the eigen value will be:
- (A) α^n (B) α
(C) n (D) n^α

[HP-SET 2018]

12. A projectile of mass 1.0 g is known to within $1 \mu\text{m s}^{-1}$. Calculate the minimum uncertainty in its position:
- (A) $5 \times 10^{26} \text{ m s}^{-1}$ (B) $5 \times 10^{26} \text{ m}$
(C) $5 \times 10^{-26} \text{ m s}^{-1}$ (D) $5 \times 10^{-26} \text{ m}$

KARNATAKA SET

[K-SET 2013]

1. The square of the wave function in quantum mechanics represents:-
- (A) A state of the system
(B) Shape of the system
(C) Probability of the system
(D) Energy of the system

[K-SET 2013]

2. The radial and angular wave function gives:-
- (A) Shape, orientation and energy, size of the orbitals respectively
(B) Energy, size and shape, orientation of the orbitals respectively
(C) Energy and size of orbitals respectively
(D) Shape and orientation of orbitals respectively

[K-SET 2013]

3. According to the Schrodinger's wave equation the energy of a particle (E_n) in one dimensional box is:-

$$\begin{aligned} \text{(A)} E_n &= \frac{n^2 h^2}{ma^2} & \text{(B)} E_n &= \frac{n^2 h^2}{4ma} \\ \text{(C)} E_n &= \frac{nh}{8ma^2} & \text{(D)} E_n &= \frac{n^2 h^2}{8ma^2} \end{aligned}$$

[K-SET 2013]

4. Perturbation theory is a technique that gives _____
- (A) Approximate solution to Schrodinger wave equation
(B) Correct solution to Schrodinger wave equation
(C) Does not deal with Schrodinger wave equation
(D) None of the above

[K-SET 2014]

5. Which one of the following statements is not true?
- (A) S orbitals are spherically symmetric
(B) A harmonic oscillator obeys Hooke's law
(C) Spin quantum number, S, for an electron $S = 1$
(D) An azeotrope is a mixture that boils without change of composition

[K-SET 2014]

6. Pick out the fermions
- (i) Electron
(ii) Proton
(iii) Neutron
(iv) Deuteron
- (A) iv is correct (B) i and iv are correct
(C) iii and iv are correct (D) i, ii and iii are correct

[K-SET 2014]

7. An even function is
- i) $f(-x) = f(x)$
ii) Product of two even functions
iii) Product of two odd functions
iv) Product of an even and an odd function
- (A) i, ii and iii are correct (B) iv is correct
(C) ii and iv are correct (D) i and iv are correct

[K-SET 2014]

8. Linear momentum of photon of wavelength 350 nm is equal to
- (A) $0.189 \times 10^{-27} \text{ kgms}^{-1}$ (B) $1.89 \times 10^{-27} \text{ kgms}^{-1}$
(C) $1.89 \times 10^{-26} \text{ kgms}^{-1}$ (D) $1.89 \times 10^{-28} \text{ kgms}^{-1}$

[K-SET 2014]

9. Match the following:-
- i) Bohr frequency condition a) $\Theta = \frac{h\nu}{k}$
ii) Debye temperature b) $\Delta E = h\nu$
iii) Linear momentum c) $\Omega\Psi = w\Psi$
iv) Eigen value equation d) h/λ
- (A) i – b, ii – a, iii – d, iv – c
(B) i – c, ii – a, iii – d, iv – b
(C) i – a, ii – b, iii – c, iv – d
(D) i – d, ii – b, iii – a, iv – c

[K-SET 2014]

10. The zero point energy of an electron is equal to:-

$$\begin{aligned} \text{(A)} \frac{h^2}{2ma^2} & \quad \text{(B)} \frac{h^2}{4ma^2} \\ \text{(C)} \frac{h^2}{8ma^2} & \quad \text{(D)} \frac{h^2}{16ma^2} \end{aligned}$$

[K-SET 2014]

11. An acceptable wave function must be:-
- (A) Continuous, have a continuous first derivative, be single valued and be square integrable
(B) Discontinuous, have a discontinuous first derivative, be single valued and be square integrable
(C) Continuous, have a continuous first derivative, be of any value and no restrictions in square integrability
(D) Both (B) and (C)

[K-SET 2015]

12. Ψ^2 measures

- (A) The energy of the electron in n^{th} orbit
 (B) Uncertainty in the position and velocity of electron
 (C) The probability of finding an electron in a given region
 (D) The hybrid character of orbitals

[K-SET 2015]

13. $\nabla^2 \Psi + \frac{8\pi^2 m(E-V)}{h^2} \Psi = 0$ is known as

- (A) Laplacian operator
 (B) Hamiltonian operator
 (C) Angular momentum
 (D) Energy operator

[K-SET 2015]

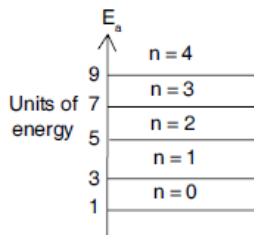
14. For a particle in a one-dimensional box of length L , in the region $0 \leq x \leq \frac{1}{4}L$, the probability of the state is given

by $p = \frac{1}{4} - \frac{\sin(\frac{n\pi}{2})}{2\pi}$. Then the probability for the particle in the state $n = 2$ and $n = 1$ are respectively:-

- (A) 0.125 and 0.25 (B) 0.375 and 0.0908
 (C) 0.25 and 0.0908 (D) 0.75 and 0.25

[K-SET 2015]

15. The figure shown in the energy level diagram corresponding to:-



- (A) Particle in a box (B) Particle tunneling
 (C) Harmonic oscillator (D) Hydrogen atom

[K-SET 2015]

16. The selection rules for hydrogenic atom are:-

- (A) $\Delta l = \pm 1$ $\Delta m_l = 0, \pm 1$ (B) $\Delta l = \pm 1$ $\Delta m_l = \pm 1/2$
 (C) $\Delta l = 0$ $\Delta m_l = \pm 1/2$ (D) $\Delta l = \pm 1$ $\Delta m_l = -1/2$

[K-SET 2015]

17. Choose the correct statement(s)

- i) Bosons are particles with half integral spin.
 ii) Symmetry number of NH_3 is 3.
 iii) The stiffer the bond, the greater is the force constant.
 iv) An aerosol is a dispersion of a liquid in a gas
 (A) ii, iii and iv are correct (B) i and ii are correct
 (C) i is correct (D) iii and iv are correct

[K-SET 2016]

18. The simplest ground state VB wave function of a HCl molecule is given as

$\Psi = \Psi_{\text{H}}(1s, 1) \Psi_{\text{Cl}}(3p_z, 2) + B$, where B represents

- (A) $\Psi_{\text{Cl}}(1s, 1) \Psi_{\text{H}}(3p_z, 3)$ (B) $\Psi_{\text{H}}(3p_z, 3) \Psi_{\text{Cl}}(1s, 3)$
 (C) $\Psi_{\text{Cl}}(2s, 2) \Psi_{\text{H}}(1s, 1)$ (D) $\Psi_{\text{H}}(1s, 2) \Psi_{\text{Cl}}(3p_z, 1)$

[K-SET 2016]

19. The unperturbed energy levels of a system are $E_0 = 0$, $E_1 = 2$ and $E_2 = 4$. The second order correction to energy for the ground state in the presence of the perturbation V for which $V_{10} = 2$, $V_{20} = 4$ and $V_{12} = 6$, is found to be

- (A) + 6 (B) - 6
 (C) - 8 (D) + 8

[K-SET 2016]

20. When a particle of mass $9.10 \times 10^{-28} \text{g}$ in a certain 1-D box goes from $n = 5$ level to the $n = 2$ level, it emits a photon of frequency $6.0 \times 10^{14} \text{cm}^{-1}$. The length of the box is:-

- (A) $1.8 \times 10^{-7} \text{m}$ (B) $1.8 \times 10^{-7} \text{cm}$
 (C) $8.1 \times 10^{-7} \text{cm}$ (D) $8.1 \times 10^{-7} \text{m}$

[K-SET 2016]

21. Hamiltonian operator (H) in $H\Psi = E\Psi$ is the operator for the ____ of the system.

- (A) Potential energy of the system
 (B) Kinetic energy of the system
 (C) Total energy of the system
 (D) Zero point energy of the system

[K-SET 2017]

22. Match the following:-

List - I (Color)

List - II

i) Green

a) 420

ii) Red

b) 620

iii) Orange

c) 530

iv) Violet

d) 700

Codes:

(A) i-d, ii-c, iii-b, iv-a

(B) i-c, ii-d, iii-b, iv-a

(C) i-a, ii-b, iii-c, iv-d

(D) i-c, ii-a, iii-b, iv-d

[K-SET 2017]

23. The following data is given (p-probability):-

X p(x)

1 0.20

3 0.25

4 0.55

The average value of x is equal to

(A) $\langle x \rangle = 3.15$ (B) $\langle x \rangle = 0.12$ (C) $\langle x \rangle = 0.24$ (D) $\langle x \rangle = 0.31$

[K-SET 2017]

24. Which of the following are linear operators?

$$\frac{d}{dx}, \frac{d^2}{dx^2}, \sqrt{\cdot}, x^2$$

$$(A) \frac{d}{dx}, \frac{d^2}{dx^2} \text{ and } x^2$$

$$(C) \sqrt{\cdot} \text{ and } x^2$$

$$(B) \sqrt{\cdot}$$

$$(D) \frac{d}{dx} \text{ and } \sqrt{\cdot}$$

[K-SET 2017]

25. Which of the following is incorrect about the de Broglie relationship?

$$(A) h = \lambda P$$

$$(C) \lambda = \frac{h}{mc}$$

$$(B) E = \frac{hc}{\lambda}$$

$$(D) E_{\text{kinetic}} = \frac{2hv}{\lambda}$$

[K-SET 2017]

26. According to the Schrodinger's wave equation, the wave function (Ψ_n) of a particle in one dimensional box is:-

$$(A) \Psi_n = A \cdot \sin\left(\frac{n\pi x}{a}\right)$$

$$(C) \Psi_n = A \cdot \sin\left(\frac{n\pi}{a}\right)$$

$$(B) \Psi_n = A \cdot \sin(n\pi x)$$

$$(D) \Psi_n = A \cdot x \sin(n\pi a)$$

[K-SET 2017]

27. Indicate which of the following function is acceptable as wave functions?

$$(A) \Psi = x$$

$$(C) \Psi = e^{-x}$$

$$(B) \Psi = e^x$$

$$(D) \Psi = e^{-x^2}$$

[K-SET 2017]

28. In time independent perturbation theory, the perturbation is:-

(A) Always present and unvarying

(B) Not present and unvarying

(C) Always present and varying

(D) Not present and varying

[K-SET 2017]

29. The wave function for the bonding molecular orbital for a heteronuclear diatomic XY molecule. Assuming that the electron on an average spends 70% of its time on nucleus X and 30% of its time on nucleus Y is:-

$$(A) \Psi_{\text{MO}} = 0.70\phi_x + 0.30\phi_y$$

$$(B) \Psi_{\text{MO}} = 0.84\phi_x + 0.55\phi_y$$

$$(C) \Psi_{\text{MO}} = 0.30\phi_x + 0.70\phi_y$$

$$(D) \Psi_{\text{MO}} = 0.55\phi_x + 0.84\phi_y$$

[K-SET 2018]

30. $\nabla^2 \Psi + \frac{8\pi^2m}{h^2} (E - V)\Psi = 0$ is known as

(A) Hamiltonian operator

(B) Laplacian operator

(C) Angular momentum

(D) Energy operator

[K-SET 2018]

31. If the function $f = e^{-ax}$ is acted upon by the operator $\frac{d}{dx}$, the eigen value and eigen function respectively are

$$(A) -a \text{ and } e^{-ax}$$

$$(C) ax \text{ and } e^{-2x}$$

$$(B) 2a \text{ and } e^{ax}$$

$$(D) \frac{d}{dx} \text{ and } e^{ax}$$

[K-SET 2018]

32. The quantum mechanical operator for kinetic energy of a particle moving in three directions is

$$(A) \frac{-h^2}{8\pi^2m} \nabla^2$$

$$(B) \frac{h}{8\pi^2m} \nabla^2$$

$$(B) \frac{h}{2\pi i} \nabla$$

$$(D) \frac{8\pi^2m}{h^2} \nabla^2$$

[K-SET 2018]

33. According to Schrodinger equation the energy of a particle (E_n) in one dimensional

$$(A) E_n = n^2 h^2 / ma^2$$

$$(C) E_n = n^2 h^2 / 8ma^2$$

$$(B) E_n = n^2 h^2 / 4ma$$

$$(D) E_n = nh / 8ma^2$$

[K-SET 2020]

34. The filling of molecular orbitals takes place according to

(A) The Aufbau principle

(B) Pauli Exclusion principle

(C) Hund's rule of maximum multiplicity

(D) All of the mentioned above

[K-SET 2020]

35. Which of the following is not a Huckel approximation in Huckel Molecular Orbital Theory (HMOT)?

(A) HMOT is applicable to planar molecules

(B) The overlap integrals S_{ij} are taken as δ_{ij} (C) The energy integrals H_{ij} are taken as alpha(D) The energy integrals H_{ij} are taken as either beta or zero

[K-SET 2020]

36. For a free particle in one direction which of the following is correct?

(A) The energy is quantized

(B) The energy can take any negative value

(C) The wave function can be normalized

(D) The energy can take any positive value

[K-SET 2020]

37. Which of the following is true for the acceptable wave function for bound state?

(A) The wave function must be real

(B) The wave function must be even Function

(C) The wave function must be quadratically integrable

(D) The wave function must anti-symmetric with respect to interchange of any two particles

[K-SET 2020]

38. For a function $f(x) = Ae^{-2ix}$ for $1 \leq x \leq 5$, which one of the following is the value A such that the function is normalised for the given range of values?

(A) Zero (B) One
(C) Two (D) Three

MAHARASHTRA SET

[MH-SET 2011]

1. The de Broglie wavelength of an electron in a Bohr orbit with radius r and quantum number n is proportional to:

(A) nr (B) $1/nr$
(C) n/r (D) r/n

[MH-SET 2011]

2. Which of the following conditions is *not* essential for an eigen function of the Hamiltonian operator to be an acceptable wave function?

(A) Continuous (B) Normalized
(C) Always positive (D) Single valued

[MH-SET 2011]

3. The number of nodes in a 3s orbital is:

(A) 0 (B) 1
(C) 2 (D) 3

[MH-SET 2011]

4. The energy of an orbital in the hydrogen atom depends on the quantum number:

(A) n (B) l
(C) m (D) s

[MH-SET 2011]

5. The three unpaired electrons on the nitrogen atom is ascribed to:

(A) Pauli's exclusion principle
(B) Aufbau principle
(C) Hund's rule
(D) Uncertainty principle

[MH-SET 2013]

6. An atom with a single electron has an atomic number of z . m and e are the mass and charge of an electron, respectively. n is the principal quantum number of a circular orbit of the electron, around the nucleus. Considering the electrostatic attraction between the electron and the nucleus to be balanced exactly by the centrifugal force arising from the circular motion of the electron, the radius of the orbit of $n = 2$ is:

(A) $\frac{4(h/2\pi)^2}{mze^2}$ (B) $\frac{2(h/2\pi)^2}{mze^2}$
(C) $\frac{4mze^2}{(h/2\pi)^2}$ (D) $\frac{2mze^2}{(h/2\pi)^2}$

[MH-SET 2013]

7. The number of quantum numbers of a free electron (one that is not bound to a nucleus) is:

(A) 0 (B) 1
(C) 2 (D) 4

[MH-SET 2013]

8. An electron of mass ' m ' is confined to a 1-D box of length ' L '. It makes a radiative transition from second excited state to ground state. The wavenumber of the photon emitted is:

(A) $\frac{h}{mL^2c}$ (B) $\frac{2h}{mL^2c}$
(C) $\frac{9h}{mL^2c}$ (D) $\frac{3h}{mL^2c}$

[MH-SET 2013]

9. The wave function of a 1-D harmonic oscillator between $x = -\infty$ and $x = +\infty$ is given by:

$$\Psi(x) = N \exp\left(-\frac{\beta x^2}{2}\right).$$

$$\left(\int_0^\infty e^{-ax^2} \frac{1}{2} \left(\frac{\pi}{a}\right)^{1/2}\right)$$

The value of N, that normalizes the function $\Psi(x)$, is:

(A) $\left(\frac{\beta}{\pi}\right)^{1/2}$ (B) $\left(\frac{\beta}{\pi}\right)^{1/4}$
(C) $\left(\frac{\beta}{2\pi}\right)^{1/2}$ (D) $\left(\frac{\pi}{\beta}\right)^{1/4}$

[MH-SET 2013]

10. The molecular orbitals of 1, 3-butadiene (not in proper order) are given below: (f_1, f_2, f_3, f_4 are the 2pz orbitals on carbon atoms 1, 2, 3 and 4 respectively).

$$\psi_1 = 0.372f_1 - 0.602f_2 + 0.602f_3 - 0.372f_4.$$

$$\psi_2 = 0.602f_1 + 0.372f_2 - 0.372f_3 - 0.602f_4.$$

$$\psi_3 = 0.372f_1 + 0.602f_2 + 0.602f_3 + 0.372f_4.$$

$$\psi_4 = 0.602f_1 - 0.372f_2 - 0.372f_3 + 0.602f_4.$$

The HOMO and LUMO in the ground state of 1, 3-butadiene are respectively:

(A) ψ_2 and ψ_3 (B) ψ_3 and ψ_2
(C) ψ_2 and ψ_4 (D) ψ_2 and ψ_1

[MH-SET 2013]

11. The Slater determinant (un-normalized) for the ground state of lithium atom is:

$$(A) \begin{vmatrix} 1s(1)\alpha(1) & 1s(1)\beta(1) & 2s(1)\alpha(1) \\ 1s(2)\alpha(2) & 1s(2)\beta(2) & 2s(2)\alpha(2) \\ 1s(3)\alpha(3) & 1s(3)\beta(3) & 2s(3)\alpha(3) \end{vmatrix}$$

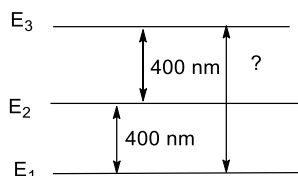
$$(B) \begin{vmatrix} 1s(1)\alpha(1) & 1s(1)\beta(1) & 1s(1)\alpha(1) \\ 1s(2)\alpha(2) & 1s(2)\beta(2) & 1s(2)\alpha(2) \\ 1s(3)\alpha(3) & 1s(3)\beta(3) & 1s(3)\alpha(3) \end{vmatrix}$$

$$(C) \begin{vmatrix} 1s(1)\alpha(1) & 1s(1)\beta(1) & 1s(1)\beta(1) \\ 1s(2)\alpha(2) & 1s(2)\beta(2) & 1s(2)\beta(2) \\ 1s(3)\alpha(3) & 1s(3)\beta(3) & 1s(3)\beta(3) \end{vmatrix}$$

$$(D) \begin{vmatrix} 1s(1)\alpha(1) & 2s(1)\alpha(1) & 2s(1)\beta(1) \\ 1s(2)\alpha(2) & 2s(2)\alpha(2) & 2s(2)\beta(2) \\ 1s(3)\alpha(3) & 2s(3)\alpha(3) & 2s(3)\beta(3) \end{vmatrix}$$

[MH-SET 2013]

12. The separation between E_1 and E_3 in the following energy level diagram will be:



- (A) 800 nm (B) 400 nm
(C) 200 nm (D) 300 nm

[MH-SET 2013]

13. The commutator of $[x^2, p_x]$ is equal to:

- (A) $\frac{hx}{\pi i}$ (B) $\frac{2hx}{\pi i}$
(C) $\frac{hx^2}{2\pi i}$ (D) $-\frac{hx}{\pi i}$

[MH-SET 2013]

14. The life time of a state that gives rise to a spectral line of width 0.1 cm^{-1} is:

- (A) 53 nm (B) 53 pm
(C) 33 nm (D) 33 pm

[MH-SET 2013]

15. The wave function for a particle in a 1-D box of length 'L' is given as $\psi = A \sin \frac{\pi x}{L}$. The value of 'A' for a box of length 50 nm is:

- (A) $5\sqrt{2} \text{ (nm)}^{1/2}$ (B) $0.2 \text{ (nm)}^{-1/2}$
(C) $0.2 \text{ (nm)}^{1/2}$ (D) $\sqrt{5}/10 \text{ (nm)}^{-1/2}$

[MH-SET 2013]

16. The quantum state of a particle in a circular path in a plane is given by:

$$\Psi_m(\phi) = \left(\frac{1}{\sqrt{2\pi}}\right) e^{-im\phi}, m = 0, \pm 1, \pm 2, \dots$$

When a perturbation $H' = P \cos \theta$ is applied (P is a constant), what will be the first order correction to the energy of the m^{th} state?

- (A) 0 (B) $P/(2\pi)$
(C) $P/(4\pi)$ (D) $Pm^2/(4\pi^2)$

[MH-SET 2013]

17. The molecular orbitals of 1, 3-butadiene (not in proper order) are given below:

(f_1, f_2, f_3, f_4 are the 2pz orbitals on carbon atoms.)

$$\psi_1 = 0.372f_1 - 0.602f_2 + 0.602f_3 - 0.372f_4$$

$$\psi_2 = 0.602f_1 + 0.372f_2 - 0.372f_3 - 0.602f_4$$

$$\psi_3 = 0.372f_1 + 0.602f_2 + 0.602f_3 + 0.372f_4$$

$$\psi_4 = 0.602f_1 - 0.372f_2 - 0.372f_3 + 0.602f_4$$

The correct order of the orbitals with increasing energy is:

- (A) $\psi_1 < \psi_2 < \psi_3 < \psi_4$ (B) $\psi_3 < \psi_2 < \psi_4 < \psi_1$
(C) $\psi_3 < \psi_4 < \psi_1 < \psi_2$ (D) $\psi_4 < \psi_3 < \psi_2 < \psi_1$

[MH-SET 2015]

18. The average value of r^2 (i.e., $\langle r^2 \rangle$) in the 1s orbital of hydrogen atom is (a_0 is the Bohr radius)

- (A) a_0 (B) $0.5 a_0^2$
(C) $3a_0^2$ (D) $1.5 a_0^3$

[MH-SET 2015]

19. The number of nodes of any orbital of hydrogen atom, other than the origin and at infinity, is given by

- (A) $n - l - 1$ (B) $n - 1$
(C) n (D) $n + l$

[MH-SET 2015]

20. An electron in the ground state of hydrogen atom is excited to a level having principle quantum no. n . It was found to absorb at wavelength λ of the electromagnetic spectrum. The value of n is (R = Rydberg constant)

- (A) $\sqrt{\frac{R}{\lambda-1}}$ (B) $\sqrt{R\lambda(\lambda-1)}$
(C) $\sqrt{\frac{R\lambda}{R\lambda-1}}$ (D) $\sqrt{\frac{R\lambda-1}{R\lambda}}$

[MH-SET 2015]

21. Based on Huckel treatment of π electron in conjugated cyclic hydrocarbons, which of the following statements is incorrect.

- (A) Lowest energy level in all such system is degenerate.
(B) Ground state of cyclobutadiene is a triplet.
(C) Delocalization energy of benzene is about 150 kJ mol^{-1}
(D) The value of resonance integral between neighbouring atoms is β .

[MH-SET 2015]

22. States arising from two p electrons are (symbols have their usual meaning)

- (A) $^3P, ^3D, ^1S$ (B) $^2D, ^1P, ^1S$
(C) $^1S, ^3P, ^1P$ (D) $^3P, ^1D, ^1S$

[MH-SET 2015]

23. The $M_s = 0$ component of triplet state arising from two electrons is (symbols have their usual meaning)

- (A) $\alpha(1) \beta(2)$
(B) $\alpha(2) \beta(1)$
(C) $\frac{1}{\sqrt{2}} [\alpha(1) \beta(2) + \beta(1) \alpha(2)]$
(D) $\frac{1}{\sqrt{2}} [\alpha(1) \beta(2) - \beta(1) \alpha(2)]$

[MH-SET 2015]

24. The degeneracy of the energy level that corresponds to energy $\frac{19}{m} \left(\frac{\pi \hbar}{a} \right)^2$ of a particle in a cubic box of length 'a' is:
- (A) 3 (B) 6
(C) 9 (D) 1

[MH-SET 2015]

25. The delocalization energy of butadiene molecule within the HMO framework of theory (β being the empirical parameter therein) is given by:
- (A) β (B) 0.472β
(C) 2β (D) 4β

[MH-SET 2015]

26. The most probable distance of 2s electron (in Å) in the ground state of H atom is:
- (A) 1.058 (B) 2.116
(C) 0.529 (D) 0.794

[MH-SET 2016]

27. The hydrogenic orbital having two radial nodes and one angular node in their appropriate representations is:
- (A) 3d (B) 4p
(C) 5d (D) 5p

[MH-SET 2016]

28. The hydrogenic orbital with its (unnormalized) spherical harmonic part being $\sin^2 \theta \sin^2 \phi$ represents which of the following orbital?
- (A) $d_{x^2-y^2}$ (B) d_{z^2}
(C) d_{yz} (D) d_{xy}

[MH-SET 2016]

29. The trial function for the particle in 1D box (with $0 \leq x \leq a$) leading to the best possible ground state energy employing the variational method should be
- (A) $x^a(a-x)^\beta$ (B) $\sin\left(\frac{\pi x}{a}\right)$
(C) $x(a-x)$ (D) $x^2(a-x)^2$

[MH-SET 2016]

30. The commutator $[\hat{x}, \hat{p}_x]$ is equal to:
- (A) $-i\hbar$ (B) 0
(C) $\hat{p}_z$ (D) 1

[MH-SET 2016]

31. The average separation of $2p_z$ electron of the H atom from the nucleus will be (a_0 Bohr radius):
- (A) $3a_0/2$ (B) $5a_0$
(C) $4a_0$ (D) a_0

[MH-SET 2016]

32. Which of the following statement is not correct about the quantum mechanical harmonic oscillator?

- (A) The amplitude of a quantum mechanical harmonic oscillator in its ground state will not exceed its classical value in lower energy states.
(B) The average values of $\langle x \rangle$ and $\langle p \rangle$ are zero.
(C) In highly excited states the quantum mechanical oscillator behaves as a classical oscillator
(D) The wave function for quantum mechanical harmonic oscillator is always either odd or even

[MH-SET 2017]

33. To every observable in classical mechanics there exists a corresponding linear in quantum mechanics.
- (A) Hamiltonian operator (B) Probability function
(C) Hermitian operator (D) Non-commutator

[MH-SET 2017]

34. Which of the following statements is not true for quantum mechanical harmonic oscillator?
- (A) The smaller the mass of the oscillation particle, the greater will be its zero-point energy, for a fixed force constant.
(B) The frequency is the same as that of a classical oscillator with the same mass and force constant.
(C) Increasing the force constant increases the spacing between adjacent energy levels.
(D) The vibrational potential energy is a constant of motion.

[MH-SET 2017]

35. The spin multiplicity of an atom in its ground state and having the outershell configuration $4s^2 3d^7$ is:
- (A) 19 (B) 15
(C) 7 (D) 4

[MH-SET 2017]

36. Which of the following is a prediction that would result from a simple HMO treatment of the butadienyl cation, $C_4H_6^+$?
- (A) The ESR coupling constant is larger for hydrogens attached to the two inner carbons.
(B) The central C-C bond has a higher π -bond order than it has in the neutral molecule.
(C) The positive charge resides mostly on the two central carbons.
(D) The MO coefficients on the central pair of carbons are larger in all of the π MOs than they are in the neutral molecule.

[MH-SET 2017]

37. Which of the following is/are acceptable quantum mechanical wave functions?
- (i) $f(X) = X^2 + 1$, for all values of X
(ii) $\Psi = 1 / (4 - X)$; $0 \leq X \leq 10$

(iii) $\Psi = 1 / (4 - X)$; $0 \leq X \leq 3$

- (A) (ii) and (iii) (B) (i) only
(C) (i) and (iii) (D) (iii) only

[MH-SET 2017]

38. The ionization energy for hydrogen atom is 13.6 eV. The ionization energy for the ground state of Li^{2+} is :

- (A) 27.2 eV (B) 6.8 eV
(C) 122.4 eV (D) 40.8 eV

[MH-SET 2017]

39. Which of the following is not a feature of Born Oppenheimer approximation?

- (A) Nuclear coordinates remain unchanged during electronic transitions
(B) Excited and ground electronic states have the same internuclear distance
(C) Electronic and vibrational motions are separable
(D) Amplitude of nuclear vibrations is smaller than that of electrons

[MH-SET 2018]

40. A particle in a one-dimensional box of length L can be excited from $n = 1$ to $n = 2$ state with frequency. If the box length is doubled, the frequency needed to achieve this transition is:

- (A) $v/4$ (B) $v/2$
(C) $2v$ (D) $4v$

[MH-SET 2018]

41. If operator $\hat{D}^n$ (n times differentiate with respect to x) operates on eigen function $e^{\alpha x}$, the eigenvalue would be:

- (A) $n\alpha$ (B) n^α
(C) α^n (D) $n! \alpha$

[MH-SET 2018]

42. The eigen functions of a rigid rotator are:

- (A) Spherical harmonics
(B) Laguerre polynomials
(C) Hermite polynomials
(D) Legendre transformers

[MH-SET 2018]

43. According to Hund's rule, most stable state for np^2 configuration is ...

- (A) $^1S_0$ (B) $^3P_0$
(C) $^3P_1$ (D) $^3P_2$

[MH-SET 2018]

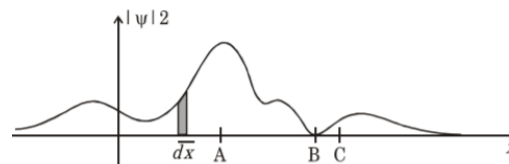
44. According to simple HMO theory, which one of the following statements about butadiene is true?

- (A) It has a non-bonding MO
(B) Exciting an electron from the HOMO to the LUMO will not change the π bond orders

- (C) Exciting an electron from the HOMO to the LUMO will not change the π charge densities
(D) It is most likely to undergo electrophilic substitution at one of the two inner carbons

[MH-SET 2018]

45. Given below is the wave function of a particle: Which of the following is correct?



- (A) The particle is more likely to be found near B
(B) The particle is more likely to be found near A
(C) The shaded area represents the energy of the particle when it travels through a distance dx
(D) The shaded area represents the amplitude of the particle in an area dx

[MH-SET 2018]

46. The de Broglie wavelength of an electron travelling with 1% speed of light is about:

(mass of electron and speed of light are 9.109×10^{-31} kg and $2.998 \times 10^8 \text{ ms}^{-1}$ respectively):

- (A) 243 m (B) 243 cm
(C) 243 Å (D) 243 pm

[MH-SET 2019]

47. If the radius of the hydrogen atom is 53 pm, the radius of the He^+ ion will be close to:

- (A) 75 pm (B) 38 pm
(C) 106 pm (D) 27 pm

[MH-SET 2019]

48. Which of the following equations corresponds to photoelectric effect?

- (A) $h\nu = W_0 + K.E$ (B) $h\nu = W_0 - K.E$
(C) $h\nu = W_0 + K.E$ (D) $h\nu = W_0 - K.E$

[MH-SET 2019]

49. The momentum operator in one-dimension is ...

- (A) $-\hbar \frac{\partial}{\partial x}$ (B) $-i \left(\hbar \frac{\partial}{\partial t} \right) - \hbar \frac{\partial}{\partial t}$
(C) $-i\hbar \frac{\partial}{\partial x}$ (D) $i - \hbar \frac{\partial}{\partial t}$

[MH-SET 2020]

50. Which of the following is correct?

- (A) In X-ray photoelectron spectroscopy valence electrons are ejected.
(B) K. E of photoelectrons increase when the intensity of the incident X-rays is increased.
(C) K. E of photoelectrons decreases when the oxidation state of the surface is increased.

(D) Number of photoelectrons emitted increases with frequency of the incident X-rays.

[MH-SET 2020]

51. A particle can occupy either the ground state at $E = 0$ or an excited state at $E > 0$. At a temperature T , the probability of the particle being in the excited state is:

- (A) 0
(B) $1 + \exp\left(-\frac{E}{K_B T}\right)$
(C) $\frac{\exp\left(-\frac{E}{K_B T}\right)}{1 + \exp\left(-\frac{E}{K_B T}\right)}$
(D) $\frac{1}{1 + \exp\left(-\frac{E}{K_B T}\right)}$

[MH-SET 2020]

52. According to Einstein's photoelectric equation, the slope of the plot of kinetic energy of the photoelectrons vs. the frequency of the incident radiation:

- (A) Will depend upon the nature of the metal that emits the photoelectrons
(B) Will depend on the intensity of the incident radiation
(C) Will depend on both the intensity of the radiation and the nature of the metal
(D) Will be the same for all metals and independent of intensity of radiation

[MH-SET 2020]

53. for a simple harmonic oscillator:

- (A) Potential energy varies linearly with displacement from equilibrium
(B) Spacing between energy levels increases with increasing energy
(C) Spacing between energy levels decreases with increasing energy
(D) Number of nodes of the wave function increases with increase in energy

[MH-SET 2020]

54. Which of the following is correct for H_2^+ ion?

- (A) A possible trial wave function for the ion is $\Psi = C_1 1S_A \pm C_2 1S_B$
(B) The coefficients of the trial wave function are not equal
(C) A possible trial wave function is $\Psi = C_1 1S_A / C_2 1S_B$
(D) The 1S orbitals are not normalised

[MH-SET 2020]

55. Which of the following is true according to variation theorem?

- (I) the ground state energy of a quantum mechanical system is zero.
(II) $\frac{\langle \Psi | H | \Psi \rangle}{\langle \Psi | \Psi \rangle} \geq E_0$
(III) $\frac{\langle \Psi | H | \Psi \rangle}{\langle \Psi | \Psi \rangle} = E_0$

(IV) The ground state energy of a quantum mechanical system is infinite.

- (A) (I) and (II)
(B) (II) only
(C) (III) only
(D) (I) and (IV)

[MH-SET 2021]

56. The ratio of the energy of the electron in the ground state of hydrogen atom to that of the electron in the first excited state of Be^{3+} is:

- (A) 1 : 4
(B) 1 : 8
(C) 2 : 9
(D) 1 : 16

[MH-SET 2021]

57. A proton is 1836 times heavier than an electron. The ratio of the de Broglie wavelengths, λ_e / λ_p is:

- (A) 1 : (1836)²
(B) (1836)^{1/2} : 1
(C) 1836 : 1
(D) (1836)² : 1

[MH-SET 2021]

58. The energy of a particle in a three-dimensional box of equal side lengths is given as:

$$E = \frac{h^2}{8ma^2} (n_x^2 + n_y^2 + n_z^2)$$

The degeneracy of energy for the levels $n_x n_y n_z = 1, 1, 1, 2, 1, 1$ and $3, 2, 1$ respectively are:

- (A) 3, 4, 6
(B) 1, 1, 1
(C) 1, 3, 6
(D) 1, 3, 3

[MH-SET 2021]

59. Ionization energy of hydrogen atom is 13.6 eV; the ionization energy for the ground state of Li^{2+} is approximately:

- (A) 27.2 eV
(B) 40.8 eV
(C) 54.4 eV
(D) 122.4 eV

[MH-SET 2023]

60. Average value of distance of an electron from nucleus in hydrogen atom in its lowest energy is expressed as:

- (A) $\langle r \rangle = \frac{1}{\pi a^3} - \int_0^\infty r^3 e^{-2r/a_0} dr$
(B) $\langle r \rangle = \frac{1}{\pi a^3} \int_0^\infty r^3 e^{-r/a_0} (e^{-r/a_0})^* dr$
(C) $\langle r \rangle = \frac{1}{\pi a^3} \left(\int_0^\infty r^3 e^{-r/a_0} dr \right) * \left(\int_0^\pi \sin \theta d\theta \right) * \left(\int_0^{2\pi} d\phi \right)$
(D) $\langle r \rangle = \frac{5}{2} a_0$

[MH-SET 2023]

61. $-\frac{\hbar^2}{2} \left(\frac{1}{m_e} + \frac{1}{m_h} \right) \frac{d^2 \psi}{dx^2} + \frac{z^2}{4\pi r} \cdot \psi = E \psi$ could be a Schrödinger equation for:

- (A) A particle in 1-D box problem
(B) Two particles in 2D box problem
(C) Simple harmonic motion between two particles
(D) Two charged particles in 1-D box problem

[MH-SET 2023]

62. The following function is acceptable as state function over the range $(-\infty \text{ to } +\infty)$:

(A) e^{-x^2} (B) $\tan x$
(C) $\cot x$ (D) xe^{-x^2}

[MH-SET 2023]

63. Calculate the wavelength of an electron accelerated through a potential of 16 V:

(Given : $(2me)^{\frac{1}{2}} = 5.4 \times 10^{-25} \frac{\text{kg.m}}{\text{s.v}^2}$)

(A) 0.307 nm (B) 0.123 nm
(C) 0.0123 nm (D) 3.07 nm

[MH-SET 2023]

64. The first order correction term to the ground state energy of hydrogen like atom is:

(A) Positive
(B) Negative
(C) Zero
(D) Can be positive or negative

[MH-SET 2023]

65. The slater determinant of helium atom is:

(A) $\psi(1,2) = \frac{1}{\sqrt{2!}} \begin{vmatrix} 1S(2)\alpha(2) & 1S(1)\alpha(1) \\ 1S(2)\beta(2) & 1S(1)\beta(1) \end{vmatrix}$
(B) $\psi(1,2) = \frac{1}{\sqrt{2!}} \begin{vmatrix} 1S(1)\alpha(1) & 1S(2)\alpha(2) \\ 1S(1)\beta(1) & 1S(2)\beta(2) \end{vmatrix}$
(C) $\psi(1,2) = \frac{-1}{\sqrt{2!}} \begin{vmatrix} 1S(1)\alpha(1) & 1S(2)\alpha(2) \\ 1S(1)\beta(1) & 1S(2)\beta(2) \end{vmatrix}$
(D) $\psi(1,2) = \frac{1}{2} \begin{vmatrix} 1S(1)\alpha(1) & 1S(2)\beta(1) \\ 1S(1)\alpha(2) & 1S(2)\beta(2) \end{vmatrix}$

[MH-SET 2023]

66. According to variation theorem, energy eigenvalue obtained from an approximate wave function is:

(A) Always equal to E_0 (B) Upper bound to E_0
(C) Lower bound to E_0 (D) Always positive

[MH-SET 2024]

67. The ground state energy of hydrogen like species is proportional to:

(A) $\frac{-R}{n^2}$ (B) $\frac{-Rz^2}{n^2}$
(C) $\frac{Rz^2}{n^2}$ (D) $\frac{R}{n}$

[MH-SET 2024]

68. For a stone weighing 100 g located within $0.1 \text{ \AA}$, which of the following statements is incorrect?

(Given: $\frac{h}{4\pi} = 5.27 \times 10^{-35} \text{ kg.m}^2.\text{s}^{-1}$).

(A) Uncertainty in velocity is negligible
(B) Both position and velocity can be determined with reasonable precision
(C) Position of stone is precisely known
(D) Velocity cannot be measured accurately

[MH-SET 2024]

69. The most probable distance of 1s electron in hydrogen like atom with atomic number 'z' is given by:

(A) $\frac{z^3}{a_0}$ (B) $z \cdot a_0$
(C) $\frac{a_0}{z}$ (D) $z^3 \cdot a_0$

[MH-SET 2024]

70. By applying variation method, the ground state energy of the electron in hydrogen atom is (in a.u.):

(A) -2.75 (B) -0.5
(C) -2 (D) 0

[MH-SET 2024]

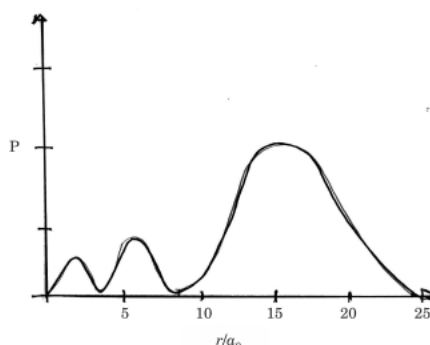
71. The result of the following operation

$\hat{A}(e^{ikx}) = \because \hat{A} = -i\hbar \frac{d}{dx}$ is:

(A) e^{ikx} (B) $\hbar e^{ikx}$
(C) $\hbar \hbar e^{ikx}$ (D) $\hbar \hbar e^{ikx^2}$

[MH-SET 2024]

72. The following sketch represents the probability density distribution for:



(A) 3s orbital (B) 3d orbital
(C) 2p orbital (D) 1p orbital

[MH-SET 2024]

73. Born interpretation of wave function is based on:

(A) Probability of finding the particle (electron) in the region r and $r + dr$ is proportional to $|\Psi|^2 dr$.
(B) Continuous property of the chosen function throughout the limits
(C) Mathematical representation of observable of the particle
(D) Normalization property of certain mathematical function

[MH-SET 2024]

74. Degeneracy in rotational levels for H-atom along z-axis for $I = 0, 1, 2, 3$ are:

(Given: $= \frac{h^2}{2I} 1.2 \times 10^{-21} \text{ J}$)

(A) 1, 2, 3, 4 (B) 1, 3, 5, 7
(C) 2, 4, 6, 8 (D) 1, 4, 9, 16

TAMILNADU SET

[TN-SET]

1. For an Eigen function α^{ihx} of linear momentum operator $\hat{p}_x$ the Eigen value is

(A) ik (B) i
(C) i (D) $\hbar$

[TN-SET]

2. _____ is Laplacian operator.

(A) $\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$ (B) $i \frac{\partial}{\partial x} + j \frac{\partial}{\partial y} + k \frac{\partial}{\partial z}$
(C) $\hat{A}\psi = \alpha\psi$ (D) $\hat{A}\hat{A}^n - \hat{A}^n\hat{A}$

TELANGANA SET

[TEL-SET 2012]

1. The value of the Planck's constant is
(A) 6.626×10^{-34} J-s (B) 6.626×10^{-27} J-s
(C) 1.380×10^{-23} JK⁻¹ (D) 9.109×10^{-31} Kg

[TEL-SET 2012]

2. If an arbitrary wave function is used to calculate the energy of a quantum mechanical system the calculated energy is never less than the true energy of the system. This statement is

(A) Heisenberg uncertainty principle
(B) Perturbation theory
(C) Law of conservation of energy
(D) Variation principle

[TEL-SET 2012]

3. Huckel MO energy levels of ethylene are

(A) $\alpha + 2\beta$; $\alpha - 2\beta$ (B) $\alpha + \beta$; $\alpha - \beta$
(C) $\alpha + 1/2\beta$; $\alpha - 1/2\beta$; (D) $\alpha + 3\beta$; $\alpha - 3\beta$

[TEL-SET 2012]

4. Match the following :

List I

I. $H\psi = E\psi$ II. $E = h\nu$ III. $|\psi|^2$ IV. $\lambda = \frac{h}{mV}$

5. Schrodinger

List II

1. Planck

2. Born

3. Dirac

4. De Broglie

	I	II	III	IV
(A)	5	1	2	4
(B)	1	2	3	4
(C)	4	5	2	1
(D)	3	2	4	1

[TEL-SET 2012]

5. In quantum mechanical tunnelling the transmission coefficient

(A) Increases with the thickness of the barrier
(B) Decreases exponentially with the thickness of the barrier
(C) Decreases with the square of the thickness of the barrier
(D) Does not depend on the thickness of the barrier

[TEL-SET 2012]

6. Example of fermions are

(A) Electron and proton (B) Photon and proton
(C) Electron and photon (D) Photons

[TEL-SET 2012]

7. Lowest allowed energy is equal to zero for a

(A) Harmonic oscillator
(B) Particle in a two dimensional box
(C) A rigid rotator
(D) Hydrogen atom

[TEL-SET 2012]

8. An electron of mass 'm' is confined to a one dimensional box of length 'l'. The frequency of the radiation absorbed during its excitation from its second energy level to third level is

(A) $\frac{5h}{8ml^2}$ (B) $\frac{h}{8ml^2}$
(C) $\frac{3h}{8ml^2}$ (D) $\frac{4h}{8ml^2}$

[TEL-SET 2013]

9. Match the following

List – I

I) Planck

II) Rydberg

III) Boltzman

IV) Avogadro

V) Faraday

List – II

1) 6.023×10^{23} mol⁻¹2) 1.381×10^{-23} JK⁻¹3) 1.0974×10^5 cm⁻¹4) 6.626×10^{-34} J-s

	1	2	3	4
(A)	V	III	II	I
(B)	IV	III	II	I
(C)	III	II	I	IV
(D)	IV	V	I	II

[TEL-SET 2013]

10. The correct statements among the following are

1) An acceptable wave function must be continuous
2) An acceptable wave function must be single valued
3) An acceptable wave function must not be square integrable
4) An acceptable wave function must have continuous first derivative

(A) 1, 2, 4 (B) 1, 2, 3
(C) 2, 3, 4 (D) 1, 3, 4

[TEL-SET 2013]

11. Identify the eigen function of the operator d/dx from the following

(A) x^2 (B) e^x
(C) x (D) $x^2 - x$

[TEL-SET 2013]

12. If an arbitrary wave function is used to calculate the energy using variation theory, the value calculated is
- (A) Never greater than the true energy
(B) Never less than the true energy
(C) Always equal to the true energy
(D) Always equal to zero

[TEL-SET 2013]

13. When the label of any two identical fermions are exchanged, the total wave function changes sign, when the labels of any two identical Bosons are exchanged the total wave function retains the same sign. This statement is

(A) Pauli principle
(B) Heisenberg uncertainty principle
(C) Variation principle
(D) Perturbation theory

[TEL-SET 2013]

14. Because the nuclei are so much more massive than the electrons, an electronic transition takes place very much faster than the nuclei can respond. This is the

(A) Heisenberg uncertainty principle
(B) Franck Condon principle
(C) Pauli principle
(D) Born-Oppenheimer approximation

[TEL-SET 2013]

15. The Balmer series in the spectrum of atomic H arise from the transitions $\left(\nabla = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \right)$

(A) $n_1 = 1$ (B) $n_1 = 2$
(C) $n_1 = 3$ (D) all of the above

[TEL-SET 2013]

16. In the orbital approximation where each electron occupies its own orbital $\psi(r_1, r_2, r_3 \dots) =$

(A) $\psi_1(r_1) + \psi_2(r_2) + \psi_3(r_3) + \dots$
(B) $-\psi_1(r_1) - \psi_2(r_2) - \psi_3(r_3) \dots$
(C) $\psi_1(r_1) \cdot \psi_2(r_2) \cdot \psi_3(r_3) \dots$
(D) $\psi_1(r_1) + \psi_2(r_2) - \psi_3(r_3) \dots$

[TEL-SET 2014]

17. The number of radial nodes for a 3s orbital is

(A) 0 (B) 1
(C) 2 (D) 3

[TEL-SET 2014]

18. Wave function of a particle at some point x has the value ψ , then the probability of finding the particle between x and $x + dx$ is proportional to

(A) $|\psi| dx$ (B) $|\psi|^3 dx$
(C) $|\psi|^2 dx$ (D) $|\psi|$

[TEL-SET 2014]

19. Zero-point energy (E_0) of a harmonic oscillator is

(A) $E_0 = h^2/8 mL^2$ (B) $E_0 = \frac{1}{2} h \nu$
(C) $E_0 = 0$ (D) $E_0 = 4h^2 / 8 m$

[TEL-SET 2014]

20. The ground state term symbol of Li is

(A) $^2S_{\frac{1}{2}}$ (B) $^2P_{\frac{1}{2}}$
(C) $^1S_{\frac{1}{2}}$ (D) $^1D_2$

[TEL-SET 2014]

21. The Hamiltonian for the internal motion of a hydrogen like atom is given by

(A) $\frac{-\hbar^2}{2\mu} \nabla^2 - \frac{Ze^2}{4\pi\epsilon_0 r}$ (B) $\frac{-\hbar^2}{2\mu} \nabla^2 + \frac{Ze^2}{4\pi\epsilon_0 r}$
(C) $\frac{-\hbar^2}{2\mu} \nabla^2$ (D) $\frac{-\hbar^2}{2\mu} \nabla^2 + \frac{1}{2} kx^2$

[TEL-SET 2014]

22. The correct statements among the following are:

1) Angular momenta of 1s, 2s and 3s orbitals are same
2) Energies of 1s, 2s and 3s orbitals are same
3) Angular momenta of 1s, 2s and 3s orbitals are different
4) Energies of 1s, 2s and 3s orbitals are different
(A) 1, 2 (B) 2, 3
(C) 3, 4 (D) 1, 4

[TEL-SET 2014]

23. The perturbation Hamiltonian $H^{(1)}$, for the first order correction to the ground-state energy for a particle in a box with a variation in the potential $v = -\epsilon \sin(\pi x/L)$ is given by

(A) $-\epsilon \sin(\pi x/L)$ (B) $\epsilon^2 \sin^2(\pi x/L)$
(C) $\epsilon^3 \sin^3(\pi x/L)$ (D) ϵ^3

[TEL-SET 2014]

24. A particle of mass 'm' is confined between two walls of a box at $x = 0$ and $x = 2L$. The potential energy is zero inside this one dimensional box but rises abruptly to infinity at the walls. The energy of this particle (E) is given by

(A) $\frac{n^2 h^2}{8mL^2}, n = 1, 2, \dots$
(B) $\frac{n^2 h^2}{32mL^2}, n = 1, 2, \dots$
(C) $\frac{n^2 h^2}{16mL^2}, n = 1, 2, \dots$
(D) $\frac{n^2 h^2}{18mL^2}, n = 0, 1, 2, \dots$

[TEL-SET 2014]

- (A) Hydrogen atom
 (B) A particle in a three dimensional box
 (C) An harmonic oscillator
 (D) A rigid rotor

[TEL-SET 2018]

39. According to Huckel Molecular Orbital Theory (HMO) the possible energy in terms of Coulombic (α) and exchange (β) integrals are

- (A) $(\alpha + \beta)$, α , $(2\alpha + \beta)$, $(2\alpha - \beta)$
 (B) $(\alpha + 2\beta)$, 2α , $(\alpha - 2\beta)$, $(2\alpha + \beta)$
 (C) $(\alpha + 2\beta)$, α , α , $(\alpha - 2\beta)$
 (D) α , α , $(\alpha + \beta)$, $(\alpha + 2\beta)$

[TEL-SET 2018]

40. The average position of a particle in one dimensional box of length L is

- (A) L (B) L/2
 (C) 2L (D) 12L

[TEL-SET 2018]

41. Average distance for 2s orbital of He+ is

- (A) $1a_0$ (B) $2a_0$
 (C) $3a_0$ (D) $4a_0$

[TEL-SET 2018]

42. The radial function 'R' depends on

1. n
 2. l
 3. m
 4. s
 (A) 1, 2 (B) 1, 4
 (C) 2, 3 (D) 3, 4

WEST BENGAL SET

[WB-SET 2015]

1. The average value of r^2 (i.e., $\langle r^2 \rangle$) in the 1s orbital of hydrogen atom is (a_0 is the Bohr radius)

- (A) a_0 (B) $0.5 a_0^2$
 (C) $3a_0^2$ (D) $1.5 a_0^3$

[WB-SET 2015]

2. The number of nodes of any orbital of hydrogen atom, other than the ones at the origin and at infinity, is given by

- (A) $n - 1 - 1$ (B) $n - 1$
 (C) n (D) $n + 1$

[WB-SET 2015]

3. An electron in the ground state of hydrogen atom is excited to a level having principal quantum no. n. It was found to absorb at wavelength 2λ of the electromagnetic spectrum. The value of n is

(R = Rydberg constant)

- (A) $\sqrt{\frac{R}{\lambda-1}}$ (B) $\sqrt{R\lambda(\lambda-1)}$
 (C) $\sqrt{\frac{R\lambda}{R\lambda-1}}$ (D) $\sqrt{\frac{R\lambda-1}{R\lambda}}$

[WB-SET 2015]

4. Based on Hückel treatment of π electrons in conjugated cyclic hydrocarbons, which of the following statements is incorrect.

- (A) Lowest energy level in all such systems is degenerate.
 (B) Ground state of cyclobutadiene is a triplet.
 (C) Delocalization energy of benzene is about 150 kJ / mole
 (D) The value of resonance integral between neighbouring atoms is B

[WB-SET 2015]

5. The $M_s = 0$ component of triplet state arising from two electrons is (symbols have their usual meaning)

- (A) $\alpha(1) \beta(2)$
 (B) $\alpha(2) \beta(1)$
 (C) $\frac{1}{\sqrt{2}} [\alpha(1) \beta(2) + \beta(1) \alpha(2)]$
 (D) $\frac{1}{\sqrt{2}} [\alpha(1) \beta(2) - \beta(1) \alpha(2)]$

[WB-SET 2017]

6. The wave function of the electron in the lowest energy state of hydrogen atom is proportional to $\exp(-r/a_0)$ where a_0 is a constant. The relative probability of finding the electron inside a volume d_v at a_0 relative to nucleus is:

- (A) 14.2 (B) 13.6
 (C) 0.71 (D) 7.1

[WB-SET 2017]

7. The set of angular parts of 2pz, 2px, 2py orbitals of hydrogen atom are:

- (A) $\cos\theta, -\sin\theta e^{i\varphi}, \sin\theta e^{-i\varphi}$
 (B) $\cos\theta, -\sin\theta e^{i\varphi}, \sin\theta e^{i\varphi}$
 (C) $\sin\theta, -\cos\theta e^{i\varphi}, \sin\theta e^{-i\varphi}$
 (D) $\cos\theta, \sin\theta \cos\varphi, \sin\theta \sin\varphi$

[WB-SET 2017]

8. For a hetero nuclear diatomic molecule which of the following statements is true?

- As the energy difference between the two interacting atomic orbitals increases
 (A) both bonding and antibonding effects increases.
 (B) both bonding and antibonding effects decreases.
 (C) bonding effect decreases but anti bonding effect increases.
 (D) bonding effect increases but anti bonding effect decreases.

[WB-SET 2017]

9. Which of the following trial wave functions may be used to calculate the first excited state of harmonic oscillator by variational method with a as a parameter?

(A) e^{-ax^2} (B) xe^{-ax^2}
(C) $(x^2 - 1)e^{-ax^2}$ (D) xe^{-ax}

[WB-SET 2017]

10. The wavelength of a charged particle (λ), varies with potential difference (E) through which it is accelerated as:

(A) $\lambda \propto \frac{1}{E}$ (B) $\lambda \propto E$
(C) $\lambda \propto E^{-1/2}$ (D) $\lambda \propto \sqrt{E}$

[WB-SET 2017]

11. If someone recognizes that $p(x) = Ce^{-2/2x^2}$ is an even function, then the value of C is determined to be:

(A) $\left(\frac{\pi a^2}{2}\right)^{1/2}$ (B) $\frac{1}{2\pi a^2}$
(C) $\frac{1}{(\pi a^2)^{1/2}}$ (D) $\frac{1}{(2\pi a^2)^{1/2}}$

[WB-SET 2017]

12. If e^{ax} is an eigenfunction of the operator d^n/dx^n , the eigenvalue is found to be:

(A) a^n (B) a
(C) na (D) $\frac{1}{a^n}$

13. The probability of finding a particle in an one-dimensional box of length a is found to be:

(A) between $-a/2$ to $a/2$ (B) between 0 and $-a/2$
(C) 0 (D) a

[WB-SET 2018]

14. The degree of degeneracy for an energy level $\frac{17h^2}{8ml^2}$ of a particle in a cubical box of side ' L ' is

(A) 5 (B) 3
(C) 4 (D) 2

[WB-SET 2018]

15. A particle of mass ' m ' moving in one – dimension between $x=a$ and $x=b$ is described by a wave function $\Psi = \frac{N}{x}$ where N is normalization constant. The average value of x is

(A) $\frac{b}{a}$ (B) $\frac{ab}{b-a} e^{b/a}$
(C) $\frac{ab}{b-a} \ln \frac{a}{b}$ (D) $\frac{ab}{b-a} [\ln b - \ln a]$

[WB-SET 2018]

16. Ψ_1 and Ψ_2 are normalized and are mutually orthogonal to each other. The normalization constant for the function $\Psi_1 + \sqrt{3}\Psi_2$ is

(A) $\frac{\sqrt{3}}{2}$ (B) 1
(C) $\frac{1}{2}$ (D) $\frac{3}{2}$

[WB-SET 2018]

17. Which of the following is correct wave function for helium atom?

(A) $1s(1) 2s(2) (\alpha_1\beta_2 - \beta_1\alpha_2)$
(B) $[1s(1) 2s(2) - 2s(1) 1s(2)] (\alpha_1\beta_2 - \beta_1\alpha_2)$
(C) $1s(1) 2s(2) \alpha_1\beta_2 - 2s(1) 1s(2) \beta_1\alpha_2 + 1s(1) 2s(2) \beta_1\alpha_2 - 2s(1) 1s(2) \alpha_1\beta_2$
(D) $[1s(1) 2s(2) - 2s(1) 1s(2)] (\alpha_1\beta_2 \cdot \beta_1\alpha_2)$

[WB-SET 2018]

18. The degeneracy of the most probable energy level for an atom of mass ' m ' of one mole of an ideal gas at TK and pressure P atm, assuming that the atom can be treated as a particle in a three-dimensional cubical box is

(A) $\frac{\sqrt{3}mKT}{h} \left(\frac{RT}{P}\right)^{\frac{1}{3}}$ (B) $\frac{2\sqrt{3}mKT}{h}$
(C) $\frac{\sqrt{3}mKT}{h} \left(\frac{RT}{P}\right)^{\frac{1}{2}}$ (D) $\frac{2\sqrt{mKT}}{h}$

[WB-SET 2018]

19. A normalized trial function for a particle in a one-dimensional box of length ' L ' is $\Psi = Nx(L-x)$

Where N is normalization constant. The upper bound to the ground state energy of the system

(A) $\frac{Nh^2}{8ml^2}$ (B) $\frac{N^2h^2}{8ml^2}$
(C) $\frac{N^2h^2l^3}{6m}$ (D) $\frac{N^2h^2l^3}{8m}$

[WB-SET 2018]

20. $\exp(-\alpha x^2)$ is an eigen function of $-\frac{d^2}{dx^2} + x^2$ provided

(A) $\alpha = \frac{1}{2}$ (B) $\alpha = 1$
(C) $\alpha = \frac{1}{\sqrt{2}}$ (D) $\alpha = 2$

[WB-SET 2020]

21. A quantum particle in a two-dimensional square box is in a state described by $n_1 = 1$ and $n_2 = 7$. State(s) in accidental degeneracy with this state is feasible with

(A) $n_1 = 7, n_2 = 1$
(B) No permissible integral values of n_1 and n_2
(C) $n_1 = 5, n_2 = 5$
(D) both of ($n_1 = 7, n_2 = 1$) and ($n_1 = 5, n_2 = 5$)

[WB-SET 2020]

22. The operator $\left(\frac{d}{dx} + x\right)^2$ equals to

(A) $\frac{d^2}{dx^2} + 2x\frac{d}{dx} + x^2 + 1$
(B) $\frac{d^2}{dx^2} + 2x\frac{d}{dx} + x^2$
(C) $\frac{d^2}{dx^2} + x\frac{d}{dx} + x^2 + 1$
(D) $\frac{d^2}{dx^2} + x^2$

[WB-SET 2020]

23. Brillouin theorem is related to
 (A) the physical significance of Hartree-Fock (HF).
 (B) failure of HF theory in reproducing ionization spectra.
 (C) consideration of electronic relaxation effect in excitation spectra.
 (D) configuration interaction between HF determinant and single excited determinant.

[WB-SET 2020]

24. If quantum-mechanical operator's P and Q are such that $[P, Q] = 1$, then $[P^2, Q^2]$ equals to
 (A) PQ (B) $2PQ + 2QP$
 (C) $4PQ$ (D) $4QP$

[WB-SET 2020]

25. Paschen-Back effect is related to
 (A) perturbation in atomic spectra due to electric field.
 (B) anharmonicity in molecular vibration.
 (C) effect of high magnetic field on atomic spectra.
 (D) L-S coupling in atomic spectra

[WB-SET 2020]

26. Due to space quantization, nuclear angular momentum can have discrete orientations about the applied magnetic field and its values (I_z) along the field axis are $I_z = Sml$, where ml can have values
 (A) $l, l-1, l-2, \dots -l$. (B) $l, l-1, l-2, \dots 2, 1, 0$.
 (C) $l, l-1, l-2, \dots 2, 1$. (D) $l, l-1, l-2, \dots -2, -1$.

[WB-SET 2021: 2Mark]

27. For a variational optimization, the following is false:
 (A) Wavefunction obtained and corresponding average energy are equally good.
 (B) The energy is always upper bound to the true ground state energy.
 (C) Energy optimized is correct upto first order in error of the wavefunction.
 (D) The method is applicable to the first excited state, provided this is orthogonal to the ground state.

[WB-SET 2021: 2Mark]

28. According to the following treatment, a homonuclear diatomic is 50% covalent:
 (A) VB treatment
 (B) Generalized VB treatment
 (C) LCAO-MO treatment
 (D) LCAO-MO-configuration interaction treatment

[WB-SET 2021: 2Mark]

29. Say, ΔE , is the energy gap between two successive levels of a one-dimensional harmonic oscillator, ΔE_B is the energy gap between two successive levels of a

quantum particle in a one-dimensional box of infinite height and wall. ΔE_n is taken as the energy gap between two successive levels of H-atom. For increasing quantum number which of the following is correct?

- (A) ΔE_v remains same, ΔE_B increases and ΔE_n decreases.
 (B) ΔE_v remains same, ΔE_B decreases and ΔE_n decreases.
 (C) ΔE_v decreases, ΔE_B increases and ΔE_n increases.
 (D) ΔE_v increases, ΔE_B increases and ΔE_n decreases.

[WB-SET 2021: 2Mark]

30. For an integral of the form $\int f_1 f_2 d\tau$ to exist, the functions f_1 and f_2 should be of the following type:
 (A) One of f_1 and f_2 must belong to the totally symmetric representation.
 (B) Functions f_1 and f_2 must belong to different irreducible representation.
 (C) There is no restriction on the representations to which they can belong.
 (D) Both f_1 and f_2 should belong to the same irreducible representation

[WB-SET 2021: 2Mark]

31. Match Column P with Column Q:

Column P	Column Q
(a) CdS/ZnS	(i) Domination of $S_0 \leftarrow S_2$ fluorescence
(b) Py C_{60}	(ii) Appearance of two numbers
(c) Azulene	(iii) Exhibition of triple exponential decay
(d) Bisporphyrin	(iv) Generation of triplet state upon irradiation by laser pulse of suitable wavelength

- | | | | |
|-----------|-------|-------|------|
| (a) | (b) | (c) | (d) |
| (A) (i) | (ii) | (iii) | (iv) |
| (B) (ii) | (iii) | (iv) | (i) |
| (C) (iv) | (iii) | (ii) | (i) |
| (D) (iii) | (iv) | (i) | (ii) |

[WB-SET 2021: 2Mark]

32. Number of independent electronic wave-functions corresponding to each of the following diatomic-molecule terms: $^1\Sigma^-$, $^3\Sigma^+$, $^3\Pi$ respectively as:
 (A) 1, 1, 2 (B) 1, 3, 6
 (C) 2, 3, 2 (D) 1, 3, 2

[WB-SET 2022: 2 Mark]

33. The commutator $\left[x, \frac{d^2}{dx^2}\right]$ equals to

- (A) $-2x$ (B) $-\frac{d}{dx}$
 (C) $-2\frac{d}{dx}$ (D) $-x$

[WB-SET 2022: 2 Mark]

34. Rayleigh-Ritz variational principle and second order Rayleigh-Schrodinger perturbation theory, when applied to find approximate energy of the ground state, gives respectively

- (A) upper bound to the true ground state energy and an energy, corrected to the energy of zeroth-order wave function.
 (B) lower bound to the true ground state energy and an energy, corrected to the energy of zeroth-order wave function.
 (C) upper bound to the true ground state energy and lower bound to the true ground state energy.
 (D) lower bound to the true ground state energy and upper bound to the true ground state energy.

[WB-SET 2022: 2 Mark]

35. Simplest wave function of i th normal mode of vibration of a polyatomic molecule can be written as follows,

$\psi_i(n) = N i e^{-(a a_i/2) \xi_i^2} \cdot H_n(\sqrt{a_i} \xi_i)$, where H_a is the Hermite polynomial of order n , N_i is normalization constant $\alpha_i = 2\pi v_i/h$, ξ_{ji} is i th normal coordinate. This shows that all wave functions of the type $\psi_i(0)$ are bases of totally symmetric representation, because

- (A) $H_0(\sqrt{\alpha_i} \xi_i) = 1$
 (B) $H_0(\sqrt{\alpha_i} \xi_i) = 1$; ξ_i^2 is symmetric.
 (C) $e^{-(a_i/2) \xi_i^2}$ is invariant of symmetry operations.
 (D) $H_n(\sqrt{\alpha_i} \xi_i)$ is invariant of symmetry operations.

[WB-SET 2023: 2 Mark]

36. Check if the following operators are Hermitian or Anti-Hermitian

$$I. \begin{bmatrix} 2 & -1 \\ i & 0 \end{bmatrix} \quad II. \begin{bmatrix} 0 & 3 \\ -3 & i \end{bmatrix}$$

- (A) I is Hermitian and II is anti-Hermitian.
 (B) Both are Hermitian.
 (C) Both are anti-Hermitian.
 (D) A is anti-Hermitian and B is Hermitian.

[WB-SET 2023: 2 Mark]

37. Consider a Potential. It is found that the energy gap between two successive states remain same. In another case the energy gap decreases with increase in quantum no. The 1st and second potential energy form,

$$(A) V_1(x) = \frac{1}{2} K x^2, V_2(x) = D(1 - e^{-\beta x})^2$$

$$(B) V_1(x) = \frac{1}{2} K x^4, V_2(x) = D(1 - e^{-\beta x})^2$$

$$(C) V_1(x) = D(1 - e^{-\beta x})^2, V_2(x) = \frac{1}{2} K x^2,$$

$$(D) V_1(x) = D(1 - e^{-\beta x})^2, V_2(x) = \frac{1}{2} K x^4,$$

[WB-SET 2023: 2 Mark]

38. Which of the following statement is correct for a three level Laser system?

Here A is Einstein coefficient for spontaneous emission and 1, 2, 3 are the first state, 2nd state and 3rd state, respectively.

- (A) The population in state 3 is larger if

$$A_{21} = A_{32}$$

- (B) The population in state 3 is larger if

$$A_{21} > A_{32}$$

- (C) The population in state 3 is larger if

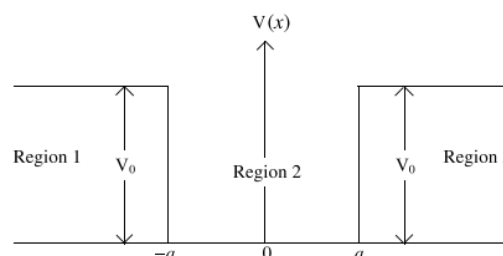
$$A_{21} < A_{32}$$

- (D) The population in state 3 is larger if

$$A_{21} = A_{32} = 0$$

[WB-SET 2023: 2 Mark]

39. Consider a particle in a finite potential well



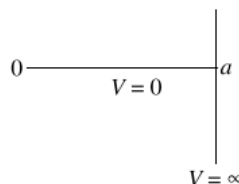
$$\begin{aligned} \text{Given } V_0 & \quad x < -a \\ V & \quad V(x) = 0 \quad -a < x < a \\ & \quad V_0 \quad x > a \end{aligned}$$

The wave function is

- (A) oscillating in region 2 and exponentially changing in region 3.
 (B) exponentially changing in region 2 and oscillating in region 3.
 (C) exponentially changing in region 2 and region 3.
 (D) linearly changing in region 2 and oscillating in region 3.

[WB-SET 2023: 2 Mark]

40. A particle is confined in a one dimensional box with the following diagram.



If the particle is perturbed by ax (where a is a small constant) inside the box, then taking the ground state unperturbed-wave function, the 1st order perturbation energy correction (E') is related to the average position $\langle x \rangle$

(A) $E' = \alpha \langle x \rangle$

(B) $E' = \langle x \rangle$

(C) $\alpha E' = \langle x \rangle$

(D) $(E')^{1/\alpha} = \langle x \rangle$

[WB-SET 2023: 2 Mark]

41. If the potential energy of a particle in a harmonic oscillator has a form $V = ax^b$, then the relation between mean potential energy (P.E) and mean kinetic energy (K.E) is given by

(A) $2 \text{ (K.E)} = b \text{ (P.E)}$

(B) $\text{K.E} = 2b \text{ (P.E)}^{1/2}$

(C) $\text{K.E} = \frac{b}{2} \text{ (P.E)}^{1/2}$

(D) $\text{K.E} = \frac{1}{2} \text{ (P.E)}$

[WB-SET 2023: 2 Mark]

42. The potential energy (V) of a bare proton with spin angular momentum (I) in a magnetic field (B) in Z direction is given by.

(A) $V = -\sqrt{B_0} I_Z$

(B) $V = \sqrt{B_0} I_Z$

(C) $V = B_0 + I_Z$

(D) $V = B_0 - \sqrt{I_Z}$

ANSWER KEY									
CHHATTISGARH SET									
1	2								
D	B								
GUJARAT SET									
1	2	3	4	5	6	7	8	9	10
D	C	B	D	B	D	D	D	B	C
11	12	13	14						
D	C	C	A						
HIMACHAL PRADESH SET									
1	2	3	4	5	6	7	8	9	10
D	D	A	A	C	A	D	C	C	C
11	12								
A	D								
KARNATAKA SET									
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C	A	A	A	D	A	C	A	B	B
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A	A	C	D	A	D	C	C		
MAHARASHTRA SET									
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C	D	B	B	A	B	A	C	B	C

21	22	23	24	25	26	27	28	29	30
B	D	C	C	B	B	B	D	B	A
31	32	33	34	35	36	37	38	39	40
B	A	C	D	D	B	D	C	D	A
41	42	43	44	45	46	47	48	49	50
C	D	D	C	B	D	D	C	C	A
51	52	53	54	55	56	57	58	59	60
C	D	D	A	B	A	B	C	D	C
61	62	63	64	65	66	67	68	69	70
D	A	A	A	B	B	B	D	C	B
71	72	73	74						
C	A	A	B						
TAMILNADU SET									
1	2								
C	A								
TELANGANA SET									
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A	D	B	A	B	B	C	C	A	B
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31	32	33	34	35	36	37	38	39	40
B	D	B	D	D	A	C	A	D	C
41	42								
B	C								
WEST BENGAL SET									
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C	A	A	B	C	A	A	C	A	D
31	32	33	34	34	36	37	38	39	40
D	B	C	A	B	A	A	B	A	A
41	42								
A	A								

QUANTUM CHEMISTRY SOLUTION

CHHATTISGARH SET

1. Solution: (D)

To find the normalization constant N for the wave function $\phi(\varphi) = Ne^{im\varphi}$ where $0 \leq \varphi \leq 2\pi$ we use the normalization condition:

$$\int_0^{2\pi} |\phi(\varphi)|^2 d\varphi = 1$$

1. First, calculate $|\phi(\varphi)|^2$:

$$|\phi(\varphi)|^2 = |Ne^{im\varphi}|^2 = |N|^2 |e^{im\varphi}|^2 = N^2$$

2. Substitute into the normalization integral:

$$\int_0^{2\pi} |N|^2 d\varphi = 1$$

$$|N|^2 \int_0^{2\pi} d\varphi = 1$$

$$|N|^2 \cdot 2\pi = 1$$

$$|N|^2 = \frac{1}{2\pi}$$

$$N = \left(\frac{1}{2\pi}\right)^{1/2}$$

Thus, the normalization constant N is $(1/2\pi)^{1/2}$, making the correct answer (D) $\frac{1}{2\pi}$.

2. Solution: (B)

The commutator of position (x) and momentum (P_x) in quantum mechanics is given by:

$$[x, P_x] = xP_x - P_x x$$

According to the canonical commutation relation:

$$[x, P_x] = i\hbar$$

GUJARAT SET

1. Solution: (D)

$$H_{operator} = -\frac{\hbar^2}{2m} \frac{\partial^2}{\partial x^2} + V(x)$$

$-\frac{\hbar^2}{2m} \frac{\partial^2}{\partial x^2}$ = operator associated with kinetic energy

$V(x)$ = potential energy

Hence, option (D) is correct.

2. Solution: (C)

Angular momentum (L) of an electron

$$(\vec{L}) = \sqrt{l(l+1)}\hbar$$

$$\hbar = \frac{h}{2\pi}$$

$$(\vec{L}) = \sqrt{2(2+1)} \frac{h}{2\pi} = \sqrt{6} \frac{h}{2\pi}$$

Hence, option (C) is correct.

3. Solution: (B)

According to HMOT, energy level for cyclobutenyl system is

$$\alpha - 2\beta$$

$$\frac{1}{2}(\alpha + 2\beta)$$

Lowest M.O. energy value for cyclobutenyl system is $\alpha + 2\beta$

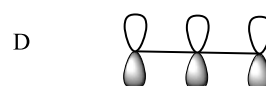
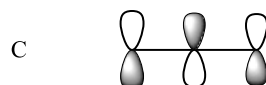
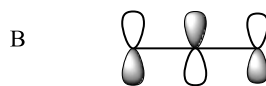
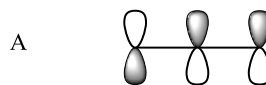
Hence, option (B) is correct.

4. Solution: (D)

Energy of π - molecular orbital is directly proportional to number of nodes.

Ground state energy is the lowest energy and it contains zero nodes

So number of nodes in option



So lowest energy π - molecular orbital for the allyl system is

$$\frac{1}{\sqrt{3}}x_1 + \frac{1}{\sqrt{3}}x_2 + \frac{1}{\sqrt{3}}x_3$$

Hence, option (D) is correct.

5. Solution: (B)

In Hückel molecular orbital (HMO) theory, the energy levels of the π -electrons are expressed as:

$$E = \alpha + 2\beta \cos\left(\frac{2\pi k}{n}\right)$$

- α is the Coulomb integral,
 - β is the resonance integral,
 - k is the energy level index,
 - n is the number of atoms in the cyclic conjugated system.
- For a cyclopentadienyl system (5 carbon atoms), $n = 5$. The highest energy level corresponds to the largest value of the cos term, which is:

$$E = \alpha + (2\cos\omega)\beta$$

where ω depends on the symmetry of the system, but the highest energy value corresponds to the positive cosine term.

Hence, option (B) is correct.

6. Solution: (D)

Hückel secular determinant for 3 atoms leads to 3 energy levels:

$$E = \alpha + 2\beta \cos\left(\frac{2\pi k}{3}\right)$$

where $k = 0, 1, 2$.

The energy levels are:

- $E_1 = \alpha + 2\beta$ (lowest energy)
 - $E_2 = \alpha$ (middle energy)
 - $E_3 = \alpha - 2\beta$ (highest energy)
2. The molecular orbitals are linear combinations of the atomic orbitals χ_1, χ_2, χ_3 . These combinations correspond to the symmetry of the system.
3. Highest energy π -M.O.: This corresponds to the antisymmetric combination of the orbitals, which leads to destructive interference and the highest energy. The correct linear combination for the highest energy orbital is:

$$\psi_{\text{highest}} = \frac{1}{\sqrt{6}}\chi_2 - \frac{1}{\sqrt{6}}\chi_3$$

Hence, option (D) is correct.

7. Solution: (D)

For a particle confined in a **1D infinite potential well** (also called a particle in a box), the energy levels are quantized and given by the formula:

$$E_n = \frac{n^2 h^2}{8ma^2}$$

m is the mass of the particle, a is the length of the box, n is a positive integer (1, 2, 3, ...).

The zero-point energy corresponds to the ground state (the first energy level)

where $n = 1$.

Zero-point energy:

$$\text{For } n = 1 : E_1 = \frac{h^2}{8ma^2}$$

Hence, option (D) is correct.

8. Solution: (D)

- (A) α -particle decay: In α -particle decay, an α -particle tunnels through the nuclear potential barrier to escape the nucleus. This is a classic example of quantum mechanical tunneling.
- (B) Inversion of ammonia: In ammonia (NH_3), the nitrogen atom tunnels through an energy barrier, causing inversion of the molecule (from one pyramidal structure to another). This is also a quantum mechanical tunneling phenomenon.
- (C) Electron transfer reactions: In some chemical reactions, especially redox reactions, electrons tunnel between

molecules or atoms through a potential energy barrier. This is another example of quantum tunneling.

(D) Combustion reactions:

Combustion reactions involve the breaking and forming of chemical bonds through the activation energy provided by heat or other means. This process is not governed by quantum mechanical tunneling but rather by classical thermal activation.

Hence, option (D) is correct.

9. Solution: (B)

The energy of a photon is related to its wavelength by the equation:

$$E = \frac{hc}{\lambda}$$

Where:

- E is the energy of the photon,
- h is Planck's constant,
- c is the speed of light,
- λ is the wavelength.

From this equation, you can see that energy (E) is inversely proportional to the wavelength (λ). As the wavelength increases, the energy decreases, which gives a curve that looks like the one in (B)—a decreasing hyperbolic curve.

Hence, option (B) is correct.

10. Solution: (C)

- (i) $\hat{x}, \hat{p}_x$: Do not commute because $[\hat{x}, \hat{p}_x] = i\hbar$.
- (ii) $\hat{p}_x, \hat{p}_x^2$: Commute because $[\hat{p}_x, \hat{p}_x^2] = 0$.
- (iii) $\hat{x}, \frac{d}{dx}$: Do not commute because $\left[\hat{x}, \frac{d}{dx}\right] = 1$.
- (iv) $\hat{x}, \frac{d^2}{dx^2}$: Commute because $\left[\hat{x}, \frac{d^2}{dx^2}\right] = 0$.

Hence, option (C) is correct.

11. Solution: (D)

This question relates to Heisenberg's Uncertainty Principle, which states:

$$\Delta x \cdot \Delta p \geq \frac{\hbar}{2}$$

- Δx is the uncertainty in position.
- Δp is the uncertainty in momentum.
- $\hbar$ is the reduced Planck's constant.

If the uncertainty in position (Δx) is zero (meaning the electron's position is exactly known), then, according to the uncertainty principle, the uncertainty in momentum (Δp) must be infinite to satisfy the inequality.

Hence, option (D) is correct.

12. Solution: (C)

- (1) $\Psi(x)$ is a well-behaved function: True, because the function is continuous, finite, and differentiable.
- (2) $\Psi(x)$ is not a normalized function: False, since the given wavefunction is already normalized.
- (3) $\Psi(x)$ is an eigenfunction of the Hamiltonian operator: True, as it satisfies the Schrödinger equation for a particle in a 1D box.
- (4) $\Psi(x)$ is an eigenfunction of the momentum operator: False, because sine functions are not eigenfunctions of the momentum operator.
- Hence, option (C) is correct.

13. Solution: (C)

To find the normalization constant A for the function $\phi_m(\phi) = Ae^{im\phi}$, we need to normalize the function over the given limits (0 to 2π), meaning that the integral of the probability density must equal 1:

$$\int_0^{2\pi} |\phi_m(\phi)|^2 d\phi = 1$$

Given that $|\phi_m(\phi)|^2 = |A|^2 e^{im\phi} e^{-im\phi} = |A|^2$, the integral becomes:

$$|A|^2 \int_0^{2\pi} d\phi = 1$$

This simplifies to:

$$|A|^2 \cdot 2\pi = 1$$

Solving for A:

$$|A|^2 = \frac{1}{2\pi}, A = \frac{1}{\sqrt{2\pi}}$$

Hence, option (C) is correct.

14. Solution: (A)

In a linear conjugated system, electrons move freely within a potential well that can be modeled using the particle-in-a-box model. The energy levels for such a system are quantized, and each level is characterized by a quantum number.

- HOMO (Highest Occupied Molecular Orbital): The highest energy level occupied by electrons in the ground state.
- LUMO (Lowest Unoccupied Molecular Orbital): The next higher energy level, which is unoccupied in the ground state but can be occupied during an excitation.

The HOMO $\rightarrow$ LUMO transition corresponds to an electron moving from the N-th energy level (HOMO) to the (N + 1)-th energy level (LUMO).

Hence, option (A) is correct.

HIMACHAL PRADESH SET**1. Solution: (D)**

Condition for well behaved (Acceptable) wave function: -

- * φ must be finite
- * φ must be single valued
- * φ must be continuous

$\sin^{-1}$ is not a single valued function. $\sin^{-1}$ is not acceptable wave function.

Hence, option (D) is correct.

2. Solution: (D)

$$[\hat{x}, \hat{p}_x^2] \text{ Trick } [\hat{x}, \hat{p}_x^n] = i\hbar n \hat{p}_x^{n-1}$$

$$px^2 = \left(-i\hbar \left(\frac{d}{dx} \right) \right)^2 = -\frac{\hbar^2 d^2}{dx^2}$$

$$[x, px^2]\varphi = \left[x \left(-\frac{\hbar^2 d^2}{dx^2} \right) - \left(-\frac{\hbar^2 d^2}{dx^2} \right) x \right] \varphi$$

$$= \left[-x \times \frac{\hbar^2 d^2 \varphi}{dx^2} + \frac{\hbar^2 d^2 (x\varphi)}{dx^2} \right]$$

$$= \left[-x \times \frac{\hbar^2 d^2 \varphi}{dx^2} + x \times \frac{\hbar^2 d^2 \varphi}{dx^2} + 2 \frac{\hbar^2 d \varphi}{dx} \right] = 2 \frac{\hbar^2 d \varphi}{dx}$$

$$[x, px^2]\varphi = 2 \frac{\hbar^2 d \varphi}{dx}$$

$$[x, px^2] = 2 \frac{\hbar^2 d}{dx}$$

$$2 \frac{\hbar^2 d}{dx} = 2i\hbar p_x = 2i\hbar \left(-\frac{i\hbar d}{dx} \right) = 2 \frac{\hbar^2 d}{dx}$$

Hence, option (D) is correct.

3. Solution: (A)

First order correction to energy = ΔE

$$\Delta E = \int_0^l \psi^{o*} \Delta H \psi^o dx$$

$$\Delta H = \lambda x \quad \psi = \sqrt{\frac{2}{l}} \sin\left(\frac{n\pi x}{l}\right)$$

$$\Delta E =$$

$$\int_0^l \sqrt{\frac{2}{l}} \sin\left(\frac{n\pi x}{l}\right) \cdot \lambda x \cdot \sqrt{\frac{2}{l}} \sin\left(\frac{n\pi x}{l}\right) dx$$

$$\Delta E =$$

$$\lambda \int_0^l \sqrt{\frac{2}{l}} \sin\left(\frac{n\pi x}{l}\right) \cdot x \cdot \sqrt{\frac{2}{l}} \sin\left(\frac{n\pi x}{l}\right) dx$$

$$\Delta E = \lambda \times \frac{2}{l} \int_0^l x \sin^2\left(\frac{n\pi x}{l}\right) dx$$

$$\Delta E = \lambda \times \frac{2}{l} \int_0^l x \frac{\left(1 - \cos\left(\frac{2n\pi x}{l}\right)\right)}{2} dx$$

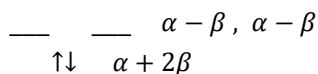
on solving integration

$$\Delta E = \frac{\lambda l}{2}$$

Hence, option (A) is correct.

4. Solution: (A)

The energy levels of cyclopropenyl cation are $\alpha + 2\beta$, $\alpha - \beta$ and $\alpha - \beta$



here one ethylene unit is present in cyclopropenyl cation

Delocalisation energy

$$= E_{total} - \text{ethylene unit energy}$$

$$= 2 \times (\alpha + 2\beta) - (2\alpha + 2\beta) = 2\beta$$

Delocalisation energy = 2β

Hence, option (A) is correct.

5. Solution: (C)

Energy of the harmonic oscillator is:-

$$E = \left(n + \frac{1}{2}\right) h\nu = \left(n + \frac{1}{2}\right) h\omega$$

for zero point energy ($n=0$)

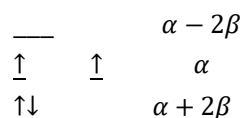
$$E(Z.P.E) = \left(n + \frac{1}{2}\right) h\omega = \left(0 + \frac{1}{2}\right) h\omega = \frac{1}{2} h\omega$$

$$E(Z.P.E) = \frac{1}{2} h\omega$$

Hence, option (C) is correct.

6. Solution: (A)

Energy levels of cyclo-butadiene



here two ethylene unit is present in cyclobutadiene

Delocalisation energy

$$= E_{total} - \text{ethylene unit energy}$$

$$= 2 \times (\alpha + 2\beta) + 2\alpha - 2(2\alpha + 2\beta) = 0$$

So Delocalisation energy in cyclobutadiene = 0

Hence, option (A) is correct.

7. Solution: (D)

Uncertainty principle also called Heisenberg uncertainty principle. According to Heisenberg uncertainty principle the position and the velocity of an object cannot both be measured exactly, at the same time.

$$\text{According to uncertainty principle: } \Delta x \cdot \Delta p \geq \frac{\hbar}{2}$$

Δx = change in position

$\Delta p = m\Delta v$ = change in momentum

Hence, option (D) is correct.

8. Solution: (C)

When hydrogen atom is placed in an electric field along the y-axis, the orbital that mixes most with the ground state 1s orbital is $2p_y$. On the y-axis $2p_y$ orbital is present so hydrogen orbital mix with $2p_y$

Hence, option (C) is correct.

9. Solution: (C)

Energy for one dimensional box is:-

$$E_n = \frac{n^2 h^2}{8ma^2} \quad \text{--- (i)}$$

$$E_{n+1} = \frac{(n+1)^2 h^2}{8ma^2} \quad \text{--- (ii)}$$

for separation between energy levels (ii) – (i)

$$E_{n+1} - E_n = \frac{(n+1)^2 h^2}{8ma^2} - \frac{n^2 h^2}{8ma^2} = \frac{h^2}{8ma^2} (n^2 + 1 + 2n - n^2) = (2n + 1) \frac{n^2 h^2}{8ma^2}$$

separation between energy levels is = $(2n + 1) \frac{n^2 h^2}{8ma^2}$

Hence, option (C) is correct.

10. Solution: (C)

$$\text{Energy} = \frac{hc}{\lambda}$$

h = planks constant = $6.626 \times 10^{-34} \text{ Js}$

c = velocity of light = $3 \times 10^8 \text{ ms}^{-1}$

λ = wavelength (in meters)

wavelength given = $200 \text{ nm} = 200 \times 10^{-9} \text{ m}$

$$E = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34} \text{ Js})(3 \times 10^8 \text{ ms}^{-1})}{200 \times 10^{-9} \text{ m}} = 9.9 \times 10^{-19} \text{ joules}$$

energy of photon is $9.9 \times 10^{-19} \text{ J}$

Hence, option (C) is correct.

11. Solution: (A)

Eigen value and Eigen function

$\hat{A}\psi = a\psi$ a = Eigen value ψ = Eigen function = e^{ax}

$\hat{A}$ = operator

$$\text{for } \hat{A} = \frac{d}{dx} \quad \hat{A}\psi = \frac{de^{ax}}{dx} = ae^{ax} \quad \text{Eigen value} = a$$

$$\text{for } \hat{A} = \frac{d^2}{dx^2} \quad \hat{A}\psi = \frac{d^2 e^{ax}}{dx^2} = a^2 e^{ax} \quad \text{Eigen value} = a^2$$

$$\text{for } \hat{A} = \frac{d^3}{dx^3} \quad \hat{A}\psi = \frac{d^3 e^{ax}}{dx^3} = a^3 e^{ax} \quad \text{Eigen value} = a^3$$

$$\text{for } \hat{A} = \frac{d^n}{dx^n} \quad \hat{A}\psi = \frac{d^n e^{ax}}{dx^n} = a^n e^{ax} \quad \text{Eigen value} = a^n$$

So eigen value for this function is a^n

Hence, option (A) is correct..

12. Solution: (D)

According to uncertainty principle: $\Delta x \cdot \Delta p \geq \frac{\hbar}{2}$

Δx = change in position

$\Delta p = m\Delta v$ = change in momentum (mass in kg)

$$\Delta x \cdot m \cdot \Delta v = \frac{\hbar}{4\pi}$$

$$\Delta x \times 0.001 \text{ kg} \times 1 \times 10^{-6} \text{ ms}^{-1} = \frac{6.626 \times 10^{-34} \text{ Js}}{4 \times 3.14}$$

$$\Delta x = 4.77 \times 10^{-26} \text{ m}$$

$$\Delta x \approx 5 \times 10^{-26} \text{ m}$$

minimum uncertainty in its position is $5 \times 10^{-26} \text{ m}$

Hence, option (D) is correct.

KARNATAKA SET

1. Solution: (C)

The square of the wave function in quantum mechanics represents the Probability density of finding the particle around a specific location in space.

Hence, option (C) is correct.

2. Solution: (B)

Shape is given by angular node or angular wave function, Radial wave function gives energy So Radial and angular wave function gives Energy, size and shape, orientation of the orbitals respectively

Hence, option (B) is correct.

3. Solution: (D)

Energy for a Particle for 1 dimensional box is $E_n = \frac{n^2 h^2}{8ma^2}$

So According to the Schrodinger's wave equation the energy of a particle (E_n) in 1 – D box = $\frac{n^2 h^2}{8ma^2}$

Hence, option (D) is correct.

4. Solution: (A)

Perturbation theory is a method for continuously improving a previously obtained approximate solution to a problem, and it is an important and general method for finding approximate solutions to the Schrodinger equation.

Hence, option (A) is correct.

5. Solution: (C)

S-Orbital are spherical So S-Orbitals are spherically symmetric

A harmonic oscillator obeys Hooke's law

Spin quantum number, S , for an electron $S = \frac{1}{2}$

An azeotrope is a mixture that boils without change of composition

Spin quantum number is incorrect here

Hence, option (C) is correct.

6. Solution: (D)

Particles with spins that come in half-integer multiple (e.g., $\pm \frac{1}{2}$, $\pm \frac{3}{2}$, $\pm \frac{5}{2}$ etc are known as Fermions

Example: - Proton, Neutron and electron

Deuteron nucleus has Ground state has spin = 1

thus it is a boson not Fermion

So i, ii and iii are fermions

Hence, option (D) is correct.

7. Solution: (A)

A Function is called an even function if its graph is unchanged under reflection in its y-axis. Suppose $f(x)$ is a function such that it is said to be an even function if

$f(-x)$ is equal to $f(x)$

ex- $f(x) = x^2$ even function

$f(-x) = (-x)^2 = x^2$ so it is an even function

$f(-x) = -f(x)$ is an odd function

$f(x) = x^3$ odd function

$f(-x) = (-x)^3 = -x^3$ so it is an odd function

property of odd function

* Product of two even functions will be an even function

* Product of two odd functions will be an even function

So statement I, ii and iii is correct

Hence, option (A) is correct.

8. Solution: (B)

According to de-Broglie hypothesis

$$\lambda = \frac{h}{mv} = \frac{h}{p}$$

$$p = \frac{h}{\lambda} = \frac{(6.626 \times 10^{-34} \text{ Js})}{350 \times 10^{-9} \text{ m}} = \frac{6.626 \times 10^{-34} \text{ kg m}^2 \text{ s}^{-2} \cdot \text{s}^{-1}}{350 \times 10^{-9} \text{ m}} =$$

$$0.0189 \times 10^{-25} \text{ kg m s}^{-1}$$

$$\text{linear momentum} = 1.89 \times 10^{-27} \text{ kg m s}^{-1}$$

Hence, option (B) is correct.

9. Solution: (A)

Energy = $\Delta E = h\nu$ (Bohr frequency condition $\nu =$ frequency)

$$\text{Debye temperature } \theta = \frac{h\nu}{k}$$

According to de-broglie hypothesis $\lambda = \frac{h}{mv} = \frac{h}{p}$;

$$p(\text{Linear momentum}) = \frac{h}{\lambda}$$

$$\text{Eigen value equation } \hat{A}\Psi = a\Psi ; \hat{\Omega}\Psi = w\Psi$$

correct match is:- i – b, ii – a, iii – d, iv – c

Hence, option (A) is correct.

10. Solution: (C)

$$\text{Energy for 1-D box} = \frac{n^2 h^2}{8ma^2}$$

for zero-point energy put $n = 1$

Zero-point energy of an electron is equal to

$$= \frac{1^2 h^2}{8ma^2} = \frac{h^2}{8ma^2}$$

Hence, option (C) is correct.

11. Solution: (A)

Condition for well behaved (Acceptable) wave function: -

* φ must be finite

* φ must be single valued

* φ must be continuous

* Square integrable

Option (a) follow these conditions

Hence, option (A) is correct.

12. Solution: (C)

The square of the wave function in quantum mechanics represents the Probability density of finding the particle around a specific location in space.

Hence, option (C) is correct.

13. Solution: (A)

$$\nabla^2 \Psi + \frac{8\pi^2 m(E-V)}{h^2} \Psi = 0$$

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$$

∇^2 is Laplacian operator

Hence, option (A) is correct.

14. Solution: (C)

$$p = \frac{1}{4} - \frac{\sin\left(\frac{n\pi}{2}\right)}{2\pi}$$

Probability for the particle in the state $n=2$ put $n=2$ here

$$\text{So } p = \frac{1}{4} - \frac{\sin\left(\frac{2\pi}{2}\right)}{2\pi} = \frac{1}{4} - \frac{\sin(\pi)}{2\pi} = \frac{1}{4} - 0 = \frac{1}{4} = 0.25$$

Probability for the particle in the state $n=1$ here

$$\text{So } p = \frac{1}{4} - \frac{\sin\left(\frac{\pi}{2}\right)}{2\pi} = \frac{1}{4} - \frac{1}{2\pi} = 0.25 - 0.1592 = 0.0908$$

the probability for the particle in the state $n = 2$ and $n = 1$ are 0.25 and 0.0908 respectively

Hence, option (C) is correct.

15. Solution: (C)

Energy for Harmonic Oscillator is

$$= \left(n + \frac{1}{2}\right) h\nu$$

Energy for Harmonic Oscillator ($n=0$)

$$= \left(0 + \frac{1}{2}\right) h\nu = \frac{1}{2} h\nu = 1x$$

Energy for Harmonic Oscillator ($n=1$)

$$= \left(1 + \frac{1}{2}\right) h\nu = \frac{3}{2} h\nu = 3x$$

Energy for Harmonic Oscillator ($n=2$)

$$= \left(2 + \frac{1}{2}\right) h\nu = \frac{5}{2} h\nu = 5x$$

Energy for Harmonic Oscillator ($n=3$)

$$= \left(3 + \frac{1}{2}\right) h\nu = \frac{7}{2} h\nu = 7x$$

So if we compare with energy we get odd multiples

Hence, option (C) is correct.

16. Solution: (A)

The selection rules for hydrogenic atom are $\Delta l = \pm 1$ $\Delta m_l = 0, \pm 1$

Hence, option (A) is correct.

17. Solution: (A)

Bosons are particles with integer spin such as 0, 1, 2 etc.

NH_3 have C_3 axis of symmetry So Symmetry number of NH_3 is 3

Strong bond has greater force constant (stiffer the bond, the greater is the force constant)

An aerosol, a system of liquid or solid particles uniformly distributed in a finely divided state through a gas usually air.

So statement (ii), (iii) and (iv) are correct

Hence, option (A) is correct.

18. Solution: (D)

The simplest ground state VB wave function of a HCl molecule is given as

$$\Psi = \Psi_{\text{H}}(1s, 1) \Psi_{\text{Cl}}(3p_z, 2) + \Psi_{\text{H}}(1s, 2) \Psi_{\text{Cl}}(3p_z, 1)$$

HCl is an ionic compound formed by electrons transfer between Hydrogen and Chloride ions.

electron 1 and 2 will lie on both the atom first it will present on chlorine and then goes to hydrogen

Hence, option (D) is correct.

19. Solution: (B)

The second order correction to energy is given by

$$\begin{aligned} E_0^{(2)} &= \frac{V_{10}^2}{E_0 - E_1} + \frac{V_{20}^2}{E_0 - E_1} \\ &= \frac{2^2}{0 - 2} + \frac{4^2}{0 - 4} \\ &= (-2) + (-4) \\ &= -6 \end{aligned}$$

Hence, option (B) is correct.

20. Solution: (B)

$$\begin{aligned} E_n &= \frac{n^2 h^2}{8ma^2} \\ \Delta E_{5 \rightarrow 2} &= h\nu = (5^2 - 2^2) \frac{h^2}{8ma^2} = 21 \frac{h^2}{8ma^2} \\ \therefore a^2 &= \frac{21h}{8m\nu} = \frac{21 \times 6.626 \times 10^{-34}}{8 \times 9.1 \times 10^{-31} \times 6 \times 10^{14}} \\ &= 3.185 \times 10^{-18} \text{m}^2 \\ \therefore a &= 1.78 \times 10^{-9} \text{m} = 1.78 \times 10^{-7} \text{cm} \\ a &= 1.8 \times 10^{-7} \text{cm} \end{aligned}$$

Hence, option (B) is correct.

21. Solution: (C)

Hamiltonian operator (H) in $\text{H}\Psi = \text{E}\Psi$

E here is Energy the sum of potential energy and kinetic energy

So Hamiltonian operator (H) in $\text{H}\Psi = \text{E}\Psi$ is the operator for the total energy of the system

Hence, option (C) is correct.

22. Solution: (A)

Violet
Blue
Green
Yellow
Orange
Red

Going from up to down side wavelength increases

So here wavelength of Red will be maximum and wavelength of violet will lowest i.e (ii)-(d) and (iv)-(a)
Hence, option (A) is correct.

23. Solution: (A)

$$\langle x \rangle = \sum x \times p(x)$$

$$\text{so } \langle x \rangle = \sum x \times p(x) = 1 \times 0.20 + 3 \times 0.25 + 4 \times 0.55$$

$$= 0.20 + 0.75 + 2.2 = 3.15$$

$$\langle x \rangle = 3.15$$

Hence, option (A) is correct.

24. Solution: (A)

Condition for linear operator is: -

$$f(x+y) = f(x) + f(y)$$

$$\sqrt{x+y} \neq \sqrt{x} + \sqrt{y} \quad \text{So } \sqrt{\quad} \text{ is not a linear operator}$$

$$(x+y)^2 \neq x^2 + y^2 \quad \text{so } x^2 \text{ is not a linear operator}$$

$$\frac{d}{dx}(x+y) = \frac{d}{dx}x + \frac{d}{dx}y \quad \text{So } \frac{d}{dx} \text{ is a linear operator}$$

$$\frac{d^2}{dx^2}(x+y) = \frac{d^2}{dx^2}x + \frac{d^2}{dx^2}y$$

$$\text{So } \frac{d^2}{dx^2} \text{ is a linear operator}$$

So only $\frac{d}{dx}$ and $\frac{d^2}{dx^2}$ is a linear operator

Hence, option (A) is correct.

25. Solution: (D)

According to de-broglie hypothesis

$$\lambda = \frac{h}{mc} = \frac{h}{mv} = \frac{h}{p} \quad p = \frac{h}{\lambda}$$

$$E = \frac{hc}{\lambda} = h\nu$$

$$E_{\text{kinetic}} = \frac{1}{2}mv^2 = \frac{1}{2}\left(\frac{p^2}{m}\right) = \frac{1}{2}\left(\frac{h^2}{m\lambda^2}\right)$$

Hence, option (D) is incorrect

26. Solution: (A)

According to the Schrodinger's wave equation, the wave function (Ψ_n) of a particle in one dimensional box

$$\text{is } \Psi_n = \sqrt{\frac{2}{a}} \sin\left(\frac{n\pi x}{a}\right) = A \sin\left(\frac{n\pi x}{a}\right)$$

Hence, option (A) is correct.

27. Solution: (C)

For a well behaved function it should follow boundary condition.

At boundary probability of finding the electron will approx. zero

$$(a) \Psi = x \quad \text{is equal to } \infty \text{ at } \infty$$

$$(b) \Psi = e^x \quad \text{is equal to } \infty \text{ at } \infty$$

$$(c) \Psi = e^{-x} \quad \text{is equal to } \infty \text{ at } -\infty$$

$$(d) \Psi = e^{-x^2} \quad \text{is equal to } 0 \text{ at } -\infty \text{ and } \infty$$

So $\Psi = e^{-x}$ is acceptable wave function

Hence, option (C) is correct.

28. Solution: (A)

In time independent perturbation theory, the perturbation is always present and unvarying
Hence, option (A) is correct.

29. Solution: (B)

$\Psi_{MO} = A\phi_x + B\phi_y$ Probability of electron spends on x = A^2 , Probability of electron spends on y = B^2

the electron on an average spends 70% of its time on nucleus X So Square the conjugate of ϕ_x for (a) 0.49 (b) 0.70 (c) 0.09 (d) 0.30

So here in option (b) electron on an average spends 70% of its time on nucleus X and 30% ($0.55^2 = 0.30$) of its time on nucleus Y

Hence, option (B) is correct.

30. Solution: (B)

$$\nabla^2 \Psi + \frac{8\pi^2 m(E-V)}{h^2} \Psi = 0$$

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$$

∇^2 is Laplacian operator

Hence, option (B) is correct.

31. Solution: (A)

For Eigen function

$$\hat{A}\psi = a\psi \quad a = \text{Eigen value} \quad \psi = e^{-ax}$$

$$\hat{A} = \text{operator} = \frac{d}{dx}$$

$$\frac{d\psi}{dx} = \frac{d}{dx}(e^{-ax}) = -ae^{-ax} = -a \times e^{-ax} = -a\psi$$

So if we compare eigen value is -a and eigen function is e^{-ax}

Hence, option (A) is correct.

32. Solution: (A)

We know Hamiltonian operator (H) in $H\Psi = E\Psi$

E here is Energy the sum of potential energy and kinetic energy

So Hamiltonian operator (H) in $H\Psi = E\Psi$ is the operator for the total energy of the system

$$\left[-\frac{\hbar^2}{2m} \frac{d^2}{dx^2} + V_{x,t} \right] = \hat{H}$$

$$\left[-\frac{\hbar^2}{2m} \frac{d^2}{dx^2} + V_{x,t} \right] = K.E + P.E$$

V = potential energy

$$\text{So } K.E \text{ is } = -\frac{\hbar^2}{2m} \frac{d^2}{dx^2} = -\frac{\hbar^2}{8\pi^2 m} \nabla^2$$

$$\text{Kinetic energy} = -\frac{\hbar^2}{8\pi^2 m} \nabla^2$$

Hence, option (A) is correct.

33. Solution: (C)

According to Schrodinger equation the energy of a particle (E_n) in one dimensional is

$$E_n = \frac{n^2 h^2}{8ma^2}$$

Hence, option (C) is correct.

34. Solution: (D)

The filling of molecular orbitals takes place according to Aufbau principle, Pauli Exclusion principle and Hund's rule of maximum multiplicity.

Aufbau principle- It states that the filling up of electrons in molecular orbitals take place according to their energy. Pauli exclusion principle- It states that no two electrons in the same atom can have identical values for all four of their quantum numbers.

Hund's rule- It states that every orbital in a subshell is singly occupied with one electron before any one orbital is doubly occupied and all electrons in singly occupied orbitals and all electrons in singly occupied orbitals have the same spin.

Hence, option (D) is correct.

35. Solution: (A)

Huckel approximation in Huckel Molecular Orbital Theory (HMOT): -

- * The overlap integrals S_{ij} are taken as δ_{ij}
- * The energy integrals H_{ij} are taken as alpha
- * The energy integrals H_{ij} are taken as either beta or zero

HMOT is applicable to planar molecule is not a Huckel approximation in HMOT

Hence, option (A) is correct.

36. Solution: (D)

For a free particle in one direction the energy can take any positive value

Hence, option (D) is correct.

37. Solution: (C)

Acceptable wave function for bound state: - The wave function must be quadratically integrable

Hence, option (C) is correct.

38. Solution: (C)

For normalisation of the wave function $1 = \int_0^1 \psi^* \psi d\tau$

$$1 = \int_1^5 (Ae^{-2ix})^* (Ae^{-2ix}) dx = \int_1^5 (Ae^{2ix}) (Ae^{-2ix}) dx$$

$$= \int_1^5 A^2 dx$$

$$1 = A^2 [x]_1^5 = A^2 [5 - 1]$$

$$1 = 4A^2$$

$$A = \pm \frac{1}{2}$$

So 2 values of A is possible

Hence, option (C) is correct.

MAHARASHTRA SET

1. Solution: (D)

$$n\lambda_n = 2\pi r_n$$

$$\lambda \propto \frac{r}{n}$$

Hence, option (D) is correct.

2. Solution: (B)

Condition for well behaved (Acceptable) wave function: -

- * φ must be finite
- * φ must be single valued
- * φ must be continuous
- * Square integrable

Normalized wave function is not essential for an eigen function of the Hamiltonian operator to be an acceptable wave function

Hence, option (B) is correct.

3. Solution: (C)

Number of Radial nodes = $n - l - 1$

number of Angular nodes = l

Total number of nodes = Angular nodes + radial nodes = $l + n - l - 1 = n - 1$

for 3s $n = 3$

number of nodes = $n - 1 = 3 - 1 = 2$

The number of nodes in a 3s orbital is 2

Hence, option (C) is correct.

4. Solution: (A)

$$\text{Energy of an orbital in the hydrogen atom} = -\frac{13.6\text{eV}}{n^2}$$

n is principle quantum number here

The energy of an orbital in the hydrogen atom depends on the principle quantum number (n)

Hence, option (A) is correct.

5. Solution: (C)

Hund's rule- It states that every orbital in a subshell is singly occupied with one electron before any one orbital is doubly occupied and all electrons in singly occupied orbitals and all electrons in singly occupied orbitals have the same spin

Hence, option (C) is correct.

6. Solution: (A)

Hence, option (A) is correct.

7. Solution: (A)

The number of quantum numbers of a free electron (one that is not bound to a nucleus) is 0

Hence, option (A) is correct.

8. Solution: (A)

According to Schrodinger equation the energy of a particle (E_n) in one dimensional is

$$E_n = \frac{n^2 h^2}{8mL^2}$$

for the wavenumber of photon emitted we have to divide it with hc

$$\text{Wave number} = \frac{n^2 h^2}{8mL^2(hc)} = \frac{n^2 h}{8mL^2 c}$$

for second excited state $n = 3$ for ground state $n=1$

So wavenumber of photon emitted is wavenumber

$$= \frac{3^2 h}{8mL^2 c} - \frac{1^2 h}{8mL^2 c} = \frac{8h}{8mL^2 c} = \frac{h}{mL^2 c}$$

Hence, option (A) is correct.

9. Solution: (B)

Normalized wave function for 1-D harmonic oscillator is

$$\left(\frac{\beta}{\pi}\right)^{1/4} \exp\left(-\frac{\beta x^2}{2}\right)$$

If we compare it with unnormalized wave-function

$$\Psi(x) = N \exp\left(-\frac{\beta x^2}{2}\right)$$

$$N = \left(\frac{\beta}{\pi}\right)^{1/4}$$

Hence, option (B) is correct.

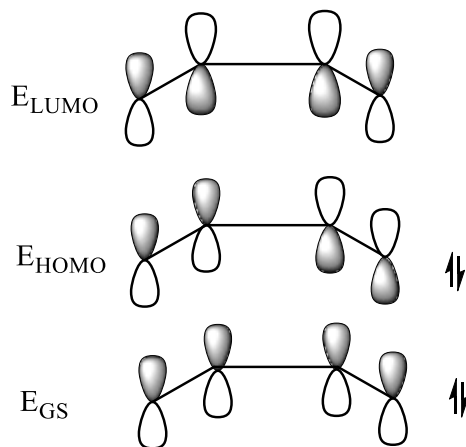
10. Solution: (C)

Energy $\propto$ number of nodes

For ground state energy number of nodes = 0

For first excited state nodes = 1

For second excited state nodes = 2



As butadiene contain $4\pi e^-$ s and one orbital occupy 2 electrons So HOMO contains 1 node and LUMO contains 2 nodes so homo is $\psi_2 = 0.602f_1 + 0.372f_2 - 0.372f_3 - 0.602f_4$. it contain 1 node

LUMO is $\psi_4 = 0.602f_1 - 0.372f_2 - 0.372f_3 + 0.602f_4$. It contains 2 nodes.

Hence, option (C) is correct.

11. Solution: (A)

The Slater determinant (un-normalized) for the ground state of lithium atom.

As it contain 3 electron so there will be a $|3 \times 3|$ matrix formation $\alpha = +\frac{1}{2}spin$

$\beta = -\frac{1}{2}spin$ So determinant will be

$$\begin{vmatrix} 1s(1)\alpha(1) & 1s(1)\beta(1) & 2s(1)\alpha(1) \\ 1s(2)\alpha(2) & 1s(2)\beta(2) & 2s(2)\alpha(2) \\ 1s(3)\alpha(3) & 1s(3)\beta(3) & 2s(3)\alpha(3) \end{vmatrix}$$

Hence, option (A) is correct.

12. Solution: (C)

$$Energy_{3-1} = Energy_{1-2} + Energy_{2-3}$$

$$\frac{hc}{\lambda_{3-1}} = \frac{hc}{400nm} + \frac{hc}{400nm} = \frac{2hc}{400nm} = \frac{hc}{200nm}$$

$$\frac{hc}{\lambda_{3-1}} = \frac{hc}{200nm}$$

$$\lambda_{3-1} = 200nm$$

Hence, option (C) is correct.

13. Solution: (D)

$$[x^2, p_x] = \frac{2xih}{2\pi} = \frac{xih}{\pi} \times \frac{i}{i} = -\frac{xh}{i\pi}$$

Hence, option (D) is correct.

14. Solution: (B)

$$\text{life time} = \frac{1}{2\pi c \Delta\nu}$$

$$\Delta\nu = \text{width}$$

$$\text{life time} = \frac{1}{2 \times 3.14 \times 3 \times 10^{10} \text{cms}^{-1} \times 0.1 \text{cm}^{-1}} = 5.3 \times 10^{-11} \text{sec} = 53 \times 10^{-12} \text{sec}$$

$$\text{life time} = 53 \text{pm seconds}$$

Hence, option (B) is correct.

15. Solution: (B)

$$\text{Normalisation condition } 1 = \int_0^L A \sin \frac{\pi x}{L} A \sin \frac{\pi x}{L} dx$$

$$1 = \frac{A^2 L}{2}$$

$$A = \sqrt{\frac{2}{L}} = \sqrt{\frac{2}{50nm}} = \sqrt{0.04} \text{ nm}^{-1/2} = 0.2 \text{ nm}^{-1/2}$$

Hence, option (B) is correct.

16. Solution: (A)

$$\text{First order correction: } -\frac{\langle \psi | H | \psi \rangle}{\langle \psi | \psi \rangle}$$

$$\langle \psi^* | H | \psi \rangle = \left(\frac{1}{\sqrt{2\pi}}\right) e^{-(-i)m\phi} P \cos \theta \left(\frac{1}{\sqrt{2\pi}}\right) e^{-im\phi} =$$

$$\frac{1}{2\pi} \int_0^\pi P \cos \theta d\theta = \frac{1}{2\pi} [\sin \theta]_0^\pi = \frac{1}{2\pi} \times 0 = 0$$

$$\text{so } \frac{\langle \psi | H | \psi \rangle}{\langle \psi | \psi \rangle} = 0$$

So first order correction to the energy of the m^{th} state is zero

Hence, option (A) is correct.

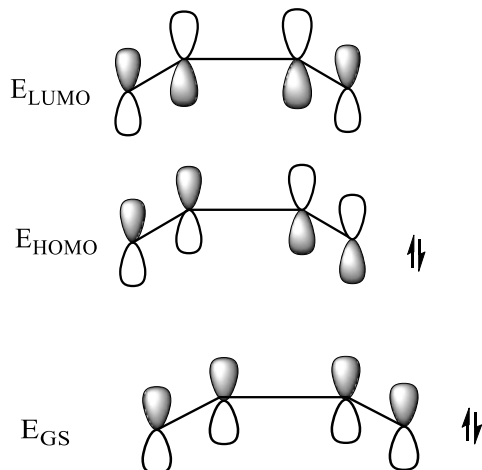
17. Solution: (B)

Energy $\propto$ number of nodes

For ground state energy number of nodes = 0

For first excited state nodes = 1

For second excited state nodes = 2



As butadiene contains $4\pi e^-$ s and one orbital occupies 2 electrons. So in ground state number of nodes = 0. HOMO contains 1 node and LUMO contains 2 nodes and orbitals above LUMO contain 3 nodes if we compare with ψ_1, ψ_2, ψ_3 and ψ_4 number of nodes is 3, 1, 0 and 2 respectively.

So energy order will be $E_3 > E_2 > E_4 > E_1$

Correct order of the orbitals with increasing energy is $\psi_3 < \psi_2 < \psi_4 < \psi_1$

Hence, option (B) is correct.

18. Solution: (C)

$$\langle r^2 \rangle = a_0^2 n^4 \left\{ 1 + \frac{3}{2} \left[1 - \frac{l(l+1) - \frac{1}{3}}{n^2} \right] \right\} \quad \text{For } 1s \text{ orbital } n=1,$$

$l=0$

put $n=1$ and $l=0$

$$\begin{aligned} \langle r^2 \rangle &= a_0^2 1^4 \left\{ 1 + \frac{3}{2} \left[1 - \frac{0(0+1) - \frac{1}{3}}{1^2} \right] \right\} \\ &= a_0^2 1^4 \left\{ 1 + \frac{3}{2} \left[\frac{4}{3} \right] \right\} = 3a_0^2 \end{aligned}$$

Hence, option (C) is correct.

19. Solution: (B)

Number of Radial nodes = $n - l - 1$

Number of Angular nodes = l

Total number of nodes = Angular nodes + radial nodes =

$$l + n - l - 1 = n - 1$$

Hence, option (B) is correct.

20. Solution: (C)

$$\text{As } \frac{1}{\lambda} = R \left[\frac{1}{n_1^2} - \frac{1}{n_2^2} \right] \quad \text{for ground state } n_1 = 1 \quad n_2 = n$$

$$\frac{1}{\lambda} = R \left[\frac{1}{1^2} - \frac{1}{n^2} \right] = R \left[1 - \frac{1}{n^2} \right]$$

multiply both side with λ

$$1 = \lambda R \left[1 - \frac{1}{n^2} \right]$$

$$\frac{1}{\lambda R} = 1 - \frac{1}{n^2}$$

$$\frac{1}{n^2} = 1 - \frac{1}{\lambda R} = \frac{\lambda R - 1}{\lambda R}$$

$$n^2 = \frac{\lambda R}{\lambda R - 1}$$

$$n = \sqrt{\frac{\lambda R}{\lambda R - 1}}$$

Hence, option (C) is correct.

21. Solution: (B)

Ground state of cyclobutene is singlet

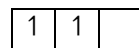
So Ground state of cyclobutadiene is a triplet is incorrect statement

Hence, option (B) is correct.

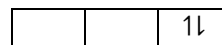
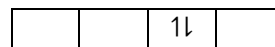
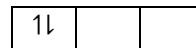
22. Solution: (D)

State arising from two p electrons

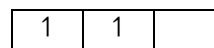
$P^2 \rightarrow$ possible states



And possible states



Ground state

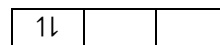


(1) $L = |1 + 0| = 1$ p term symbol

$$S = \frac{1}{2} + \frac{1}{2} = 1 \quad 2S + 1 \Rightarrow 2 \times 1 + 1 = 3$$

3_p

(2)



+1 0

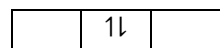
0

$L \Rightarrow |1 + 1| = 2$ d term symbol

$$S = \frac{1}{2} + \frac{1}{2} = 1 \quad 2S + 1 \Rightarrow 2 \times 0 + 1 = 1$$

1_D

(3)



$$+1 \quad 0 \quad -1$$

$$L = |0 + 0| = 0 \rightarrow S$$

$$S = \left| \frac{1}{2} - \frac{1}{2} \right| = 0 \rightarrow 2 \times 0 + 1 = 1$$

$$1_S$$

(4)

		1↓
--	--	----

$$+1 \quad 0 \quad -1$$

$$L = |-1 - 1| = +2 \rightarrow D$$

$$S = \left| \frac{1}{2} - \frac{1}{2} \right| = 0 \rightarrow 2 \times 0 + 1 = 1$$

$$1_D$$

States arising from two p electrons are $3P, 1D, 1S$

Hence, option (D) is correct.

23. Solution: (C)

$$M_S = 0$$

$$\alpha \text{ means } +\frac{1}{2} \rightarrow 1 \text{ spin}$$

$$\beta \text{ means } -\frac{1}{2} \rightarrow 1 \text{ spin}$$

$$\text{Triplet state arising from two electron is } \frac{1}{\sqrt{2}} [\alpha(1)\beta(2) + \beta(1)\alpha(2)]$$

Hence, option (C) is correct.

24. Solution: (C)

Energy for 3-D cubic box is

$$\left[E_n = (n_x^2 + n_y^2 + n_z^2) \frac{h^2}{8ma^2} \right] \text{-----(i)}$$

$h \rightarrow$ plank's constant

$m =$ mass

$a =$ length of box

$n =$ principle quantum no.

$$\text{given energy is } = \frac{19}{m} \left(\frac{\pi h}{a} \right)^2$$

$$= \frac{19}{m} \left(\frac{\pi h}{2\pi a} \right)^2$$

$$= \frac{19}{m} \frac{h^2}{4a^2} \times \frac{2}{2}$$

$$= \frac{19h^2}{ma^2} \times \frac{2}{8}$$

$$= \frac{38h^2}{8ma^2} \text{-----(ii)}$$

By comparing (i) and (ii) we get

$$(n_x^2 + n_y^2 + n_z^2) = 38$$

Possible values of n_x, n_y, n_z is

$$(n_x^2 + n_y^2 + n_z^2) = 38$$

$$6 \quad 1 \quad 1 \rightarrow \text{degeneracy} = 3 \quad (611, 161, 116)$$

$$5 \quad 3 \quad 2 \rightarrow \text{degeneracy} = 6 \quad (532, 523, 325, 352, 235, 253)$$

$$\text{So total degeneracy} = 3 + 6 = 9$$

Hence, option (C) is correct.

25. Solution: (B)

Butadiene energy order

$$\alpha - 1.618\beta$$

$$\alpha - 0.618\beta$$

$$1\downarrow \alpha + 0.618\beta$$

$$1\downarrow \alpha + 1.618\beta$$

Buta diene have 2π electrons so,

Delocalisation energy = total energy – ethylene unit energy

$$\text{Total energy} = 2(\alpha + 1.62\beta) + 2(\alpha + 0.62\beta)$$

$$= 2\alpha + 3.24\beta + 2\alpha + 1.24\beta$$

$$\text{Total energy} = 4\alpha + 4.48\beta$$

Here in buta diene it contain 2π electron

So it contains 2 ethylene unit

So energy of ethylene unit is

$$= 4\alpha + 4.48\beta - (4\alpha + 4\beta)$$

$$D.E. = 0.48\beta$$

Hence, option (B) is correct.

26. Solution: (B)

most probable distance

$$\langle r \rangle = \frac{a_0}{2} [3n^2 - l(l+1)]$$

For 2S electron

$$n=2 \quad l=0$$

$$\langle r \rangle = a_0 [3 \times 2^2 - 0(0+1)]$$

$$= \frac{a_0}{2} [12] = 6a_0$$

$$\langle r \rangle = 6a_0$$

$$1.5a_0 = 0.529A^0$$

$$a_0 = 0.3526A^0$$

$$\langle r \rangle = 6 \times 0.3526A^0$$

$$\langle r \rangle = 2.116A^0$$

Most probable distance of 2S electron in the ground state of H atom is $2.116A^0$

Hence, option (B) is correct.

27. Solution: (B)

$$\text{Number of radial nodes} = 2 = n - l - 1$$

$$\text{number of angular nodes} = 1 = l$$

if we put the value of l in radial nodes equation $2 = n - 1 - 1$

n comes out to be 4 and l is 1 so it is 4p orbital

Hence, option (B) is correct.

28. Solution: (D)

$$y_{l,m} \propto \sin^{|m|} \theta \cos^{l-|m|} \theta e^{im\phi}$$

for d-orbital (l is 2) and for d_{xy} $m = -2$

if we put the value of l and m we get

$$y_{2,-2} \propto \sin^{|-2|} \theta \cos^{2-|-2|} \theta e^{i(-2)\phi} \propto \sin^2 \theta e^{-2i\phi}$$

$$e^{-2i\phi} = \sin^2 \phi$$

$$\text{So } y_{2,-2} \propto \sin^2 \theta e^{-2i\phi} \propto \sin^2 \theta \sin^2 \phi$$

Hence, option (D) is correct.

29. Solution: (B)

For trial wave function fulfil the boundary condition

* it should be zero at boundary

* it should be continuous

So $\sin\left(\frac{\pi x}{a}\right)$ fulfil all condition

Hence, option (B) is correct.

30. Solution: (A)

$$\begin{aligned} [\hat{x}, \hat{p}_x] \\ \hat{p}_x &= -\hbar \frac{d}{dx} \\ [\hat{x}, \hat{p}_x] &= [\hat{x}, -\hbar \frac{d}{dx}] \\ [\hat{x}, \hat{p}_x] &= \left[-\hat{x}i\hbar \frac{d}{dx} - \left(-i\hbar \frac{d}{dx} x \right) \right] \psi \\ [\hat{x}, \hat{p}_x] &= \left[-\hat{x}i\hbar \frac{d\psi}{dx} + i\hbar \frac{dx\psi}{dx} \right] \\ &= -\hat{x}i\hbar \frac{d\psi}{dx} + \hat{x}i\hbar \frac{d\psi}{dx} + i\hbar\psi \\ &= i\hbar\psi \\ [\hat{x}, \hat{p}_x] &= i\hbar \end{aligned}$$

Hence, option (A) is correct.

31. Solution: (B)

Average separation of $2P_z$ electron

$$= \frac{a_0}{2} [3n^2 - l(l+1)]$$

For $2P_z$ electron

$$n=2, l=1$$

$$\text{Average separation} = \frac{a_0}{2} [3 \times 2^2 - 1(1+1)]$$

$$\frac{a_0}{2} [12 - 2] = \frac{a_0}{2} \times 10$$

$$\text{Average separation} = 5a_0$$

Hence, option (B) is correct.

32. Solution: (A)

Incorrect statement about the quantum mechanical harmonic oscillator is the amplitude of a quantum mechanical harmonic oscillator in its ground state will not exceed its classical value in lower energy states

Hence, option (A) is correct.

33. Solution: (C)

Every operator in quantum mechanics is a Hermitian operator.

So to every observable in classical mechanics there exists a corresponding linear Hermitian operator in quantum mechanics.

Hence, option (C) is correct.

34. Solution: (D)

For quantum mechanical harmonic oscillator

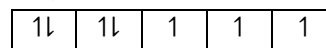
The vibrational potential energy is not constant for a motion

So statement (D) is incorrect

Hence, option (D) is correct.

35. Solution: (D)

electronic configuration is



$3d^7$



$4s^2$

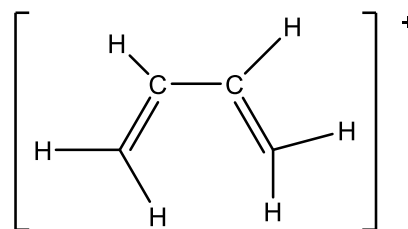
$$S = \frac{1}{2} + \frac{1}{2} + \frac{1}{2} = \frac{3}{2}$$

$$\text{Spin multiplicity} = 2S + 1 = 2 \times \frac{3}{2} + 1 = 4$$

So spin multiplicity is 4

Hence, option (D) is correct.

36. Solution: (B)



- If positive charge delocalise on carbon atoms
- Double bond character on the central C-C bond will be higher on delocalisation of positive charge
So central C-C have more π bond character
So the central C-C bond has higher π bond order than it has in the neutral molecule
Hence, option (B) is correct.

37. Solution: (D)

For acceptable wave function it should follow boundary condition

For

(i) $f(x) = x^2 + 1$

At $x = 0 \rightarrow f(x) = 1$

At $x = -\infty \rightarrow f(x) = \infty$

(ii) $\psi = \frac{1}{4-x}$

At $x = 0 \leq x \leq 10$

At $x = 9$

$\psi = -\frac{1}{5}$

(iii) $\psi = \frac{1}{4-x}$

At $x = 0, \psi = \frac{1}{4}$

At $x = 1, \psi = \frac{1}{3}$

At $x = 2, \psi = \frac{1}{2}$

At $x = 3, \psi = 1$

So acceptable quantum mechanical wave function

(iv) $\psi = \frac{1}{4-x}; 0 \leq x \leq 3$

Hence, option (D) is correct.

STATISTICAL THERMODYNAMICS

PERVIOUS YEAR QUESTION

ANDHRA PRADESH SET

[AP-SET 2012]

- The correct statements among the following:
 - The canonical ensemble is an imaginary collection of replications of the actual system with a common temperature.
 - The Boltzmann distribution gives the number of the molecules in each state of a system at any temperature.
 - The partition function is an indication of the number of thermally accessible states at the temperature of interest.
 - The molecular partition function can be written as $q = q^T q^R q^V q^E q^N$

(A) 1 and 2 (B) 2, 3 and 4
(C) 1, 3 and 4 (D) All are correct

[AP-SET 2013]

- The instantaneous configuration of a system of N molecules is the specification of the set of populations $n_0, n_1, \dots$ of the energy levels $\epsilon_0, \epsilon_1, \dots$. The weight W of a configuration is given by

(A) $W = N/n_0! n_1! \dots$ (B) $W = N!/n_0! n_1! \dots$
(C) $W = N!/n_0! n_1! \dots$ (D) $W = \frac{n_0! n_1!}{N} \dots$

[AP-SET 2013]

- In a micro canonical ensemble all the systems are individually isolated and have the same

(A) Energy (B) Temperature
(C) Chemical potential (D) All of the above

[AP-SET 2014]

- The molar partition function (Q) for system of distinguishable independent molecules is related to the molecular partition (q) as

(A) $Q = q^N$ (B) $Q = Nq$
(C) $Q = RT \left(\frac{\partial \ln q}{\partial \ln v} \right)$ (D) $Q = \frac{q^N}{N}$

[AP-SET 2014]

- The partition function (Q) is related to Gibbs free energy as

- (A) $-RT \left[\ln \left(\frac{Q}{N_A} \right) \right]$
(B) $-RT \left[\ln \left(\frac{Q}{N_A} \right) + 1 - \left(\frac{\partial \ln Q}{\partial \ln V} \right)_T \right]$
(C) $-RT \left[\ln \left(\frac{Q}{N_A} \right) - 1 + \left(\frac{\partial \ln Q}{\partial \ln V} \right)_T \right]$
(D) $RT \left[\ln \left(\frac{Q}{N_A} \right) + 1 - \left(\frac{\partial \ln Q}{\partial \ln V} \right)_T \right]$

[AP-SET 2019]

- Match the following in Column – I with Column – II.

$$\left(\alpha + \beta E_i = \frac{E_i - \mu}{k_B T} \right)$$

Column – I	Column – II
1. Maxwell-Boltzmann statistics	a. $Q = q^N$
2. Bose-Einstein statistics	b. $Q = \frac{q^N}{N!}$
3. Distinguishable canonical partition function	c. $n_i = \frac{g_i}{e^{\alpha + \beta E_i - 1}}$
4. Indistinguishable canonical partition function	d. $n_i = \frac{g_i}{e^{\alpha + \beta E_i}}$
	e. $n_i = \frac{g_i}{e^{\alpha + \beta E_i + 1}}$

(A) 1-b, 2-c, 3-a, 4-d

(B) 1-e, 2-b, 3-a, 4-c

(C) 1-a, 2-e, 3-b, 4-c

(D) 1-d, 2-c, 3-a, 4-b

[AP-SET 2019]

- Number of configurations to distribute the two indistinguishable objects in three boxes is

(A) 4 (B) 9
(C) 2 (D) 6

CHHATTISGARH SET

[CG-SET 2017: 2 Mark]

- Match the following:

(a) Translational Partition Function (Degree of Freedom 3)	(i) $\frac{1}{\left(1 - e^{-\frac{h\nu}{kT}} \right)}$
(b) Rotational Partition Function (Linear molecule, Degree of Freedom 2)	(ii) $\frac{8\pi^2 I kT}{\sigma h^2}$
(c) Rotational Partition Function (Non linear molecule, degree of Freedom 3)	(iii) $\frac{8\pi^2 (8\pi^3 I_A I_B I_C)^{1/2} (kT)^{3/2}}{\sigma h^3}$

(d) Vibrational Partition Function (Per normal mode, degree of Freedom 1)	(iv) $\frac{(2\pi mkT)^{3/2}}{h^3}$
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Codes:

(a)	(b)	(c)	(d)
(A) (i)	(iii)	(ii)	(iv)
(B) (ii)	(iii)	(i)	(iv)
(C) (iv)	(ii)	(iii)	(i)
(D) (iii)	(iv)	(i)	(ii)

GUJARAT SET

[GJ-SET 2017]

1. The canonical partition function of a system of independent indistinguishable particle is given by:

(A) $Q = \frac{q^N}{N!}$ (B) $Q = \frac{q}{N!}$
 (C) $Q = \frac{N!}{q^N}$ (D) $Q = \infty$

[GJ-SET 2017]

2. If Q is the molar partition function then the work function A is given by:

(A) $A = kT \ln Q$ (B) $A = QT$
 (C) $A = -kT \ln Q$ (D) $A = \frac{kT}{\ln Q}$

[GJ-SET 2017]

3. The translation partition function of a hydrogen molecule confined in a 100 ml flask at 298 K (mol. Wt. of $H_2 = 2.016$) is:

(A) 2.8×10^{20} (B) 2.8×10^{25}
 (C) 2.8×10^{26} (D) 2.8×10^{27}

[GJ-SET 2018]

4. If Q is the molar partition function then the work function A is given by:

(A) $A = kT \ln Q$ (B) $A = QT$
 (C) $A = -kT \ln Q$ (D) $A = kT / \ln Q$

[GJ-SET 2019]

5. Which of the following partition function is volume dependent?

(Where, q_{rot} = rotational partition function, q_{vib} = vibrational partition function q_{trans} = translation partition function, q_{ele} = electronic partition function)

(A) q_{rot} (B) q_{vib}
 (C) q_{trans} (D) q_{ele}

[GJ-SET 2019]

6. If g_i and n_i are the degeneracy and occupation number of the i^{th} energy level, the conditions. Under which Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics give identical results is:

(A) $g_i/n_i \ll 1$ (B) $g_i/n_i \gg 1$
 (C) g_i/n_i is indeterminate (D) $g_i/n_i < 0$

7. The one dimensional (having side length, l_z) translational partition function, q_{trans} is

(A) $\left(\frac{2\pi mkT}{h}\right) \cdot V$ (B) $\frac{(2\pi mkT)^{1/2}}{h} \cdot V$
 (C) $\left(\frac{2\pi mkT}{h}\right)^{1/2} \cdot V$ (D) $\frac{(2\pi mkT)^{1/2}}{h} \cdot l_x$

8. For fermi – Dirac distribution, which one of the following statement is not true?

(A) Applicable to indistinguishable particles.
 (B) Restriction on the number of particles in a given quantum state.
 (C) At absolute zero, energy is taken to be zero.

9. For the partition function, q which is not true?

(A) Its minimum value is 1
 (B) It possesses unit of energy
 (C) It increases with increase in temperature
 (D) It is dimensionless quantity

[GJ-SET 2022]

10. In terms of partition function, internal energy, U is equal to

(A) $-NK_b T \left(\frac{\partial \ln q}{\partial T}\right)_V$ (B) $NK_b T \left(\frac{\partial \ln q}{\partial T}\right)_V$
 (C) $-NK_b T^2 \left(\frac{\partial \ln q}{\partial T}\right)_V$ (D) $NK_b T^2 \left(\frac{\partial \ln q}{\partial T}\right)_V$

[GJ-SET 2022]

11. At _____ temperature, Fermi-Dirac distribution approaches to Maxwell-Boltzmann distribution.

(A) Absolute zero (B) Constant
 (C) High (D) Low

[GJ-SET 2023: Set 2]

12. The translational partition function for oxygen atoms at 300 K contained in a volume of 22.414 dm^3 is given as 2.8×10^{30} . Calculate thermal de Broglie wavelength λ .

(A) $2 \times 10^{-8} \text{ cm}$ (B) $2 \times 10^{-11} \text{ m}$
 (C) $2 \times 10^{-12} \text{ m}$ (D) $2 \times 10^{-9} \text{ m}$

KARNATAKA SET

[K-SET 2013]

1. The partition function is defined as $q = \sum_j e^{-\beta \epsilon_j}$ and is an indication of ____
- (A) The number of thermally accessible states at the temperature of interest
- (B) The number of thermally accessible states at 273°K
- (C) The number of thermally accessible states at 25°C
- (D) The number of thermally inaccessible states at 25°C

[K-SET 2013]

2. For distinguishable independent molecules we write $Q = q^N$. For indistinguishable independent molecules it is _____

(A) $Q = Nq$

(B) $Q = e^{-q^N}$

(C) $Q = \frac{q^N}{N!}$

(D) $Q = \frac{N!}{q^N}$

[K-SET 2016]

3. Though a constant shift of energy levels of a system changes the partition function, the properties that do not change are:-
- (A) Average energy and heat capacity
- (B) Average energy and entropy
- (C) Average energy, entropy and heat capacity
- (D) Entropy and heat capacity

[K-SET 2017]

4. Match the following:-

i) Molecular partition function

a) $K_0 = \frac{K_1}{K_1}$

ii) Arrhenius equation

b) $q = \sum g_i e^{-\beta \epsilon_i}$

iii) Boltzmann constant

c) $K = Ae^{-E_a/RT}$

iv) Principle of detailed balance

d) $\frac{R}{N}$

(A) i-b, ii - c, iii - d, iv - a

(B) i-c, ii - b, iii - d, iv - a

(C) i-a, ii - b, iii - c, iv - d

(D) i-d, ii - c, iii - b, iv - a

[K-SET 2017]

5. The ratio of the translational partition function of D_2 and H_2 at the same temperature and volume is:-
- (A) 1 (B) 2.83
- (C) 2 (D) 0.5

[K-SET 2017]

6. The Boltzmann distribution gives the numbers of molecules in each state of a system at any temperature:- $N_i = N e^{-\beta \epsilon_i/q}$, where

(A) $\beta = \frac{1}{T}$

(B) $\beta = \frac{1}{RT}$

(C) $\beta = \frac{T}{R}$

(D) $\beta = RT$

MAHARASHTRA SET

[MH-SET 2015]

1. Which of the following statement is incorrect?
- (A) An isolate system can be represented by a microcanonical ensemble.
- (B) A system adiabatically coupled to a heat bath can be represented by a canonical ensemble.
- (C) An open system can be represented by a grand canonical ensemble.
- (D) Gibbs free energy is proportional to the logarithm of grand canonical partition function

[MH-SET 2015]

2. At 300 K, ratio of translation partition function of one mole of a gas of distinguishable particles, to that of one mole of a gas of indistinguishable particle, is (N_a = Avogadro No.)
- (A) $600 \times N_a$ (B) $N_a!$
- (C) $\frac{1}{N_a!}$ (D) $\log N_a!$

[MH-SET 2015]

3. Rotational temperature of HCl and HF molecules are 15.2 K and 30.2 K respectively. Ratio of rotational partition function of HCl to that of HF at 300 K is approximately
- (A) 0.25 (B) 0.5
- (C) 4 (D) 2

[MH-SET 2015]

4. Ratio of molar translational partition function of N_2 at 300 K to that at 600 K is given by
- (A) 1:2 (B) $1:2^{3/2}$
- (C) $2^{3/2}:1$ (D) $1:2^{5/2}$

[MH-SET 2015]

5. A system has three states of energy 0, ϵ and 2ϵ . Degeneracies of the states are 1, 4 and 4 respectively. Partition function of the system at high temperature is
- (A) 1 (B) $1 + e^{-\epsilon} + e^{-2\epsilon}$
- (C) $\frac{1}{1 + 4e^{-\epsilon} + 4e^{-2\epsilon}}$ (D) $(1 + 2e^{-\epsilon})^2$

[MH-SET 2015]

6. In the expression of rotational partition function the symmetry number, σ , is found in the denominator. Its value for methane is
- (A) 4 (B) 12
- (C) 3 (D) 8

[MH-SET 2017]

7. An ensemble representing an open, isothermal system at constant temperature, volume and chemical potential is known as:
- (A) grand-canonical ensemble
- (B) canonical ensemble

- (C) micro-canonical ensemble
(D) isothermal isobaric ensemble

[MH-SET 2018]

8. The distribution function for identical indistinguishable particles can be represented by the equation $N_j = \frac{g_j}{e^{(\epsilon_j - \mu)/kT + a}}$, which of the following statements is correct?
(A) $a = +1$ for Bose-Einstein statistics
(B) $a = -1$ for Fermi-Dirac statistics
(C) $a = +1$ for Fermi-Dirac statistics
(D) $a = 1/2$ for Bose-Einstein statistics

[MH-SET 2019]

9. In a grand canonical ensemble, a system X of fixed volume is in contact with a large reservoir Y, then
(A) X can exchange only energy with Y
(B) X can exchange only particles with Y
(C) X can exchange neither energy nor particles with Y
(D) X can exchange both energy and particles with Y
10. In a canonical ensemble, a system X of fixed volume is in contact with a large reservoir Y, then:
(A) X can exchange only energy with Y
(B) X can exchange only particles with Y
(C) X can exchange neither energy nor particles with Y
(D) X can exchange both energy and particles with Y

[MH-SET 2021]

11. According to Fermi-Dirac the statistics following assumption is made:
(A) the particles are distinguishable and any number of particles may occupy the same energy level
(B) the particles are indistinguishable and any number of particles may occupy a given energy level
(C) the particles are indistinguishable but only one particle may occupy a given energy level
(D) the particles are distinguishable and only one particle may occupy a given energy level

[MH-SET 2023]

12. For a system with non-degenerate zero energy state and doubly degenerate upper state (with energy E), the partition function is:
(A) $2e^{-E/KT}$
(B) $2 + e^{E/KT}$
(C) $3e^{-E/KT}$
(D) $1 + 2e^{-E/KT}$

[MH-SET 2023]

13. The excess population of nuclear spins in lower state is given by:
(A) $\frac{n_{lower}}{n_{lower} + n_{upper}}$
(B) $\frac{n_{lower} + n_{upper}}{n_{lower} - n_{upper}}$
(C) $\frac{n_{upper} - n_{lower}}{n_{upper} + n_{lower}}$
(D) $\frac{n_{lower} - n_{upper}}{n_{lower} + n_{upper}}$

14. The molecular population is:
(A) Proportional to $(2J+1)^{-1}$
(B) Proportional to $\frac{(2J+1)}{e^{-E/kT}}$
(C) Proportional to $(2J+1)e^{-E/kT}$
(D) Proportional to $(2J+1)^{-1} e^{E/kT}$

[MH-SET 2024]

[MH-SET 2024]

15. For Maxwell-Boltzmann statistics which of the following statements is incorrect?
(A) System has constant volume and constant total energy
(B) The energy levels are eigen values of Schrodinger equation
(C) All possible distributions are equally probable
(D) Total energy depend upon the number of energy levels available

[MH-SET 2024]

16. When in an ensemble the condition of constant temperature is replaced by the constant energy condition, each system behaves as:
(A) Closed
(B) Open
(C) Isolated
(D) Condensed

[MH-SET 2024]

17. At what temperature, the population in $v = 1$ level of I would become half the population in ground energy level? (Given : $\frac{hc\bar{\nu}}{k} = 346.5 \text{ K}$)
(A) 773 K
(B) 500 K
(C) 227 K
(D) 300 K

TAMILNADU SET

[TN-SET]

1. The correct equation representing Maxwell-Boltzmann distribution law is
(A) $n_i = g_i e^{-(\alpha + \beta \epsilon_i)}$
(B) $n_i = g_i e^{-(\alpha - \beta \epsilon_i)}$
(C) $n_i = \frac{g_i}{[e^{(\alpha + \beta \epsilon_i)} - 1]}$
(D) $n_i = \frac{g_i}{[1 - e^{(\alpha + \beta \epsilon_i)}]}$

TELANGANA SET

[T-SET 2012]

1. The correct statements among the following:
1. The canonical ensemble is an imaginary collection of replications of the actual system with a common temperature.
2. The Boltzmann distribution gives the number of the molecules in each state of a system at any temperature.

3. The partition function is an indication of the number of thermally accessible states at the temperature of interest.
4. The molecular partition function can be written as $q = q^T q^R q^V q^E$.

Codes:

- (A) 1 and 2 (B) 2, 3 and 4
(C) 1, 3 and 4 (D) All are correct

[T-SET 2013]

2. The instantaneous configuration of a system of N molecules is the specification of the set of populations $n_0, n_1, \dots$ of the energy levels $\epsilon_0, \epsilon_1, \dots$. The weight W of a configuration is given by

- (A) $W = N! / n_0! n_1! \dots$ (B) $W = N! / n_0! n_1! \dots$
(C) $W = N! / n_0! n_1! \dots$ (D) $W = \frac{n_0! n_1!}{N} \dots$

[T-SET 2013]

3. In a micro canonical ensemble all the systems are individually isolated and have the same

- (A) Energy (B) Temperature
(C) Chemical potential (D) All of the above

[T-SET 2014]

4. The molar partition function (Q) for system of distinguishable independent molecules is related to the molecular partition (q) as

- (A) $Q = q^N$ (B) $Q = Nq$
(C) $Q = RT \left(\frac{\partial \ln q}{\partial \ln V} \right)$ (D) $Q = \frac{q^N}{N}$

[T-SET 2014]

5. The partition function (Q) is related to Gibbs free energy as

- (A) $-RT \left[\ln \frac{Q}{N_A} \right]$
(B) $-RT \left[\ln \frac{Q}{N_A} + 1 - \left(\frac{\partial \ln Q}{\partial \ln V} \right)_T \right]$
(C) $-RT \left[\ln \frac{Q}{N_A} - 1 + \left(\frac{\partial \ln Q}{\partial \ln V} \right)_T \right]$
(D) $RT \left[\ln \frac{Q}{N_A} + 1 - \left(\frac{\partial \ln Q}{\partial \ln V} \right)_T \right]$

[T-SET 2017]

6. In how many ways can two particles be distributed in five states of an energy level if the particles follow Bose-Einstein statistics?

- (A) 30 (B) 15
(C) 20 (D) 10

[T-SET 2018]

7. In a ground canonical ensemble all the systems have constant

1. Volume
2. Chemical Potential
3. Energy

4. Temperature

- (A) 2, 3 (B) 3, 4
(C) 2, 4 (D) 1, 2

[T-SET 2018]

8. For distinguishable independent molecules, the relationship between canonical partition function (Q) and molecular partition function (q) is

- (A) $Q = q/N$ (B) $Q = q^N$
(C) $Q = q$ (D) $Q = q/N!$

WEST BENGAL SET

[WB-SET 2015]

1. Which of the following statements is incorrect?
(A) An isolated system can be represented by a microcanonical ensemble.
(B) A system adiabatically coupled to a heat bath can be represented by a canonical ensemble.
(C) An open system can be represented by a grand canonical ensemble.
(D) Gibbs free energy is proportional to the logarithm of grand canonical partition function.

[WB-SET 2015]

2. At 300 K, ratio of translational partition function of one mole of a gas of distinguishable particles, to that of one mole of a gas of indistinguishable particles, is (N_A = Avogadro No.)
(A) $600 \times N_A$ (B) $N_A!$
(C) $\frac{1}{N_A!}$ (D) $\log N_A!$

[WB-SET 2015]

3. Rotational temperatures of HCl and HF molecules are 15.2 K and 30.2 K respectively. Ratio of rotational partition function of HCl to that of HF at 300 K is approximately

- (A) 0.25 (B) 0.5
(C) 4 (D) 2

[WB-SET 2015]

4. Ratio of molar translational partition function of N_2 at 300 K to that at 600 K is given by

- (A) 1:2 (B) 1: $2^{3/2}$
(C) $2^{3/2}$:1 (D) 1: $2^{5/2}$

[WB-SET 2015]

5. A system has three states of energy 0, ϵ and 2ϵ . Degeneracies of the states are 1, 4 and 4 respectively. Partition function of the system at high temperatures is

- (A) 1 (B) $1 + e^{-\epsilon} + e^{-2\epsilon}$
(C) $\frac{1}{1 + 4e^{-\epsilon} + 4e^{-2\epsilon}}$ (D) $(1 + 2e^{-\epsilon})^2$

[WB-SET 2022: 2 Mark]

18. Consider a 2-state system at thermal equilibrium with equal degeneracy where the excited state is higher in energy by 0.1 eV. The ratio of population of the excited state to that of the ground state at a temperature, for which $k_B T = 0.05 \text{ eV}$, is

- (A) $\sqrt{e}^2$ (B) $e^{-3/2}$
 (C) e^{-2} (D) e^{-1}

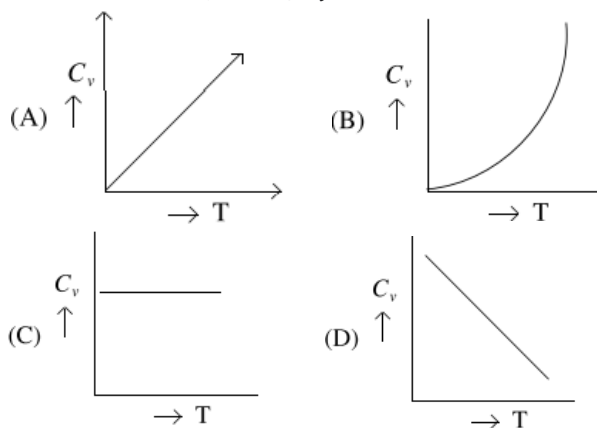
[WB-SET 2023: 2 Mark]

19. The rotational contribution to the molar Helmholtz free energy of a diatomic molecule may be expressed as $\frac{RT}{\sigma} \ln \left(\frac{T}{\sigma \theta_r} \right)$. The terms, namely, R , T , σ and θ_r , have their usual meanings.

- (A) $-R \ln \left(\frac{T}{\sigma \theta_r} \right)$ (B) $-RT \ln \left(\frac{T}{\sigma \theta_r} \right)$
 (C) $-R \ln \left(\frac{1}{\sigma \theta_r} \right)$ (D) $-RT \ln \left(\frac{1}{\sigma \theta_r} \right)$

[WB-SET 2023: 2 Mark]

20. A partition function has the form $Z = e^{\alpha T}$ where α is a const. The corresponding C_v would look like

**ANSWER KEY****ANDHRA PRADESH SET**

1	2	3	4	5	6	7	
D	C	A	A	B	D	D	

CHHATTISGARH SET

1	
B	

GUJARAT SET

1	2	3	4	5	6	7	8	9	10
A	C	C	C	C	B	D	C	B	D

11	12	
C	B	

KARNATAKA SET

1	2	3	4	5	6	
A	C	D	A	B	B	

MAHARASHTRA SET

1	2	3	4	5	6	7	8	9	10
B	B	D	B	D	B	A	C	D	A

11	12	13	14	15	16	17	
C	D	D	C	D	C	B	

TAMILNADU SET

1	
B	

TELANGANA SET

1	2	3	4	5	6	7	8	
D	C	A	A	B	B	C,D	B	

WEST BENGAL SET

1	2	3	4	5	6	7	8	9	10
D	B	D	B	D	B	B	C	B	D

11	12	13	14	15	16	17	18	19	20
A	C	C	C	D	B	A	C	B	A

SOLUTIONS

ANDHRA PRADESH SET

1. Solution: (D)

Canonical ensemble: - It is a closed system

⇒ Number of particles, volume and temperature are fixed.

Boltzmann distribution

$$n_i = g_i e^{\frac{-E_i}{KT}}$$

n_i = Number of particles in i th level.

total number of particles = $N_0 + N_1 + n_2 + N_3 - \dots$

$$\left[N = \sum_{i=0}^i n_i = \sum_{i=0}^i g_i e^{\frac{-E_i}{KT}} \right]$$

$$\left[q = \sum g_i e^{\frac{-E_i}{KT}} \right] \text{ Partition function (q)}$$

partition function indicates how the particles are distributed b/w various energy levels/state.

partition function is multiplicative in nature

$$Q = Q_{trans} Q_{rot} Q_{vib} Q_{electric} Q_{nuclear}$$

So all the statements are correct.

Hence, option (D) is correct.

2. Solution: (C)

For Distinguishable particles with given occupation number.

$$W = \frac{N!}{\pi n_i!}$$

W = number of arrangements

N = number of particles

n_i = number of particles in i th state.

$$W = \frac{N!}{n_0! \times n_1! \times n_2! \times n_3! \dots}$$

Hence, option (C) is correct.

3. Solution: (A)

On the basis of interaction of members of ensemble with the surrounding: -

Micro – canonical ensemble: - (Isolated system)

* Number of particles, volume and energy are fixed Or constant

So in a micro canonical ensemble all the systems are individually isolated and have the same energy.

Hence, option (A) is correct.

4. Solution: (A)

For N – kind of distribution of N – particles

$$Q = q^N$$

$$q = \sum g_i e^{\frac{-\varepsilon_i}{KT}}$$

$g_i \Rightarrow$ Degeneracy of its state.

$\varepsilon_i \Rightarrow$ Energy of i th state.

$$Q = q^N$$

Q = total partition function

q = molecular partition function

N = Number of distinguishable independent molecules

Hence, option (A) is correct.

5. Solution: (B)

Gibbs free energy (ΔG)

$$\Delta G = -RT \left[\ln \left(\frac{Q}{N_A} \right) + 1 - \left(\frac{\partial \ln Q}{\partial \ln V} \right)_T \right]$$

Hence, option (B) is correct.

6. Solution: (D)

$$1. \text{ Maxwell - Boltzmann statistics} \rightarrow (d) n_i = \frac{g_i}{e^{\alpha + \beta E_i}}$$

$$2. \text{ Bose - Einstein statistics} \rightarrow (C) n_i = \frac{g_i}{e^{\alpha + \beta E_i} - 1}$$

$$3. \text{ Distinguishable Canonical partition function} \rightarrow (a) Q = q^N$$

$$4. \text{ Indistinguishable Canonical partition function} \rightarrow (b) Q = \frac{q^N}{N!}$$

So correct match is 1-d, 2-c, 3-a, 4-b

Hence, option (D) is correct.

7. Solution: (D)

9 distinguishable particles (0 0) (both same)

$$(1) \text{ NO restriction } M = 3 \quad N = 2$$

M = No. of boxes = 3

N = No. of particles = 2

$$\begin{array}{ccccccc} & & 00 & & 0 & 0 \\ & 00 & & 0 & & 0 \\ 00 & & & 0 & 0 & & \end{array}$$

$$W = 6$$

$$W = \frac{(N+M-1)!}{N!(M-1)!} = \frac{(2+3-1)!}{2!(3-1)!} = \frac{4!}{2!2!}$$

$$\Rightarrow \frac{4 \times 3 \times 2!}{2! \times 2!} = 6$$

Number of configurations to distribute the two distinguishable objects in three boxes is 6

Hence, option (D) is correct.

CHHATTISGARH SET

1. Solution: (B)

(a) Translational Partition Function (Degree of Freedom 3):

The translational partition function for a gas in three dimensions is given by:

$$Z_{trans} = \frac{(2\pi m k T)^{3/2}}{h^3}$$

So, (a) matches with (iv).

- (b) Rotational Partition Function (Linear molecule, Degree of Freedom 2):

For linear molecules, the rotational partition function is:

$$Z_{\text{rot}} = \frac{8\pi^2 I k T}{h^2}$$

So, (b) matches with (ii).

- (c) Rotational Partition Function (Non-linear molecule, Degree of Freedom 3):

For non-linear molecules, the rotational partition function is:

$$Z_{\text{rot}} = \frac{8\pi^2 (8\pi^3 I_A I_B I_C)^{1/2} (kT)^{3/2}}{h^3}$$

So, (c) matches with (iii).

- (d) Vibrational Partition Function (Per normal mode, Degree of Freedom 1):

The vibrational partition function for a harmonic oscillator is given by:

$$Z_{\text{vib}} = \frac{1}{1 - e^{-h\nu/kT}}$$

So, (d) matches with (i).

Hence, option (B) is correct.

GUJARAT SET

1. Solution: (A)

$$N = \sum_{i=0}^{\infty} n_i = \sum_{i=0}^{\infty} g_i e^{-E_i/kT}$$

$$q = \sum g_i e^{-E_i/kT}$$

Partition function (q)

For indistinguishable particles.

$$Q = \frac{q^N}{N!}$$

Q = total partition function

q = molecular partition function

N = total number of particles

Hence, option (A) is correct.

2. Solution: (C)

Helmholtz Energy (A)

$$A = U - TS$$

$$A = U - T \left[Nk \ln \frac{q}{N} + \frac{U}{T} + NK \right]$$

$$\Rightarrow U - NkT \ln \frac{q}{N} - U - NkT$$

$$A = -NkT \ln \frac{q}{N} - NkT$$

$$A = -KT \left[N \ln \frac{q}{N} + N \right]$$

$$A = -kT [N(\ln q - \ln N) + N]$$

$$A = -kT [N \ln q - N \ln N + N] = -kT [N \ln q - \ln N!]$$

$$A = -kT [\ln q^N - \ln N!]$$

$$A = -kT \left[\ln \frac{q^N}{N!} \right]$$

$$Q = \frac{q^N}{N!} = \text{canonical partition function}$$

$$A = -KT \ln Q$$

Hence, option (C) is correct.

3. Solution: (C)

$$q_{\text{trans}} = \frac{(2\pi m k_B T)^{1.5} V}{h^3}$$

Given: - temperature 298K

$$\text{mass} = 2.016 \text{ g per mole} = 2.016 \times 1.67 \times 10^{-27} \text{ kg}$$

$$K_B = 1.38 \times 10^{-23}$$

$$\text{volume} = 100 \text{ ml} = 10^{-4} \text{ m}^3$$

$$q_{\text{trans}} = \frac{(2\pi m k_B T)^{1.5} V}{h^3} =$$

$$\frac{(2 \times 3.14 \times 2.016 \times 1.67 \times 10^{-27} \text{ kg} \times 1.38 \times 10^{-23} \times 298 \text{ K})^{1.5}}{(6.626 \times 10^{-34})^3} \times 10^{-4} =$$

$$2.78 \times 10^{26}$$

$$q_{\text{trans}} = 2.8 \times 10^{26}$$

Hence, option (C) is correct.

4. Solution: (C)

Helmholtz Energy (A)

$$A = U - TS$$

$$A = U - T \left[Nk \ln \frac{q}{N} + \frac{U}{T} + NK \right]$$

$$\Rightarrow U - NkT \ln \frac{q}{N} - U - NkT$$

$$A = -NkT \ln \frac{q}{N} - NkT$$

$$A = -KT \left[N \ln \frac{q}{N} + N \right]$$

$$A = -kT [N(\ln q - \ln N) + N]$$

$$A = -kT [N \ln q - N \ln N + N] = -kT [N \ln q - \ln N!]$$

$$A = -kT [\ln q^N - \ln N!]$$

$$A = -kT \left[\ln \frac{q^N}{N!} \right]$$

$$Q = \frac{q^N}{N!} = \text{canonical partition function}$$

$$A = -KT \ln Q$$

Hence, option (C) is correct.

5. Solution: (C)

$$q_{\text{trans}} = \frac{(2\pi m k_B T)^{1.5} V}{h^3}$$

$$q_{\text{rotational}} = \frac{8\pi^2 I k_B T}{h^2}$$

$$q_{\text{vibrational}} = \frac{1}{1 - e^{-h\nu/kT}}$$

Without Z.P.E

$$q_{\text{electronic}} = \sum_{i=1}^i g_i e^{-E_i/kT}$$

If we look at translation partition function volume is present so. q_{trans} is volume dependent.

Hence, option (C) is correct.

6. Solution: (B)

g_i = degeneracy of i th level

n_i = number of particle at i th level

If degeneracy of i th level is very much greater than the number of particles at i th level. At this condition Maxwell – Boltzmann, base – Einstein and fermi – Dirac statistics give identical results.

$$g_i \gg n_i \rightarrow \frac{g_i}{n_i} \gg 1$$

Hence, option (B) is correct.

7. Solution: (D)

Applicable to electrons

$$\text{translational partition function} = \frac{(2\pi m k T)^{3/2}}{h^3} V$$

Translational particle function for 1 dimensional

$$= \frac{(2\pi m k T)^{1/2}}{h} \times l_x$$

Hence, option (D) is correct.

8. Solution: (C)

For Fermi – Dirac distribution

- applicable to indistinguishable particles
- restriction on the number of particles in a given quantum state
- applicable to electrons
- at absolute zero, energy is not zero

Hence, option (C) is correct.

9. Solution: (B)

$$\text{Partition function } (q) = \sum n_i = \sum g_i \times e^{-\frac{E_i}{kBT}}$$

Partition function is a dimension less quantity

It does not possess any unit

Hence, option (B) is correct.

10. Solution: (D)

In statistical mechanics, the internal energy U is related to the partition function q by the following equation:

$$U = Nk_B T^2 \left(\frac{\partial \ln q}{\partial T} \right)_V$$

Hence, option (D) is correct.

11. Solution: (C)

- The Fermi-Dirac distribution applies to particles obeying the Pauli exclusion principle (like electrons), which cannot occupy the same quantum state.
- The Maxwell-Boltzmann distribution applies to classical particles, which do not obey this restriction.

At high temperatures, the effects of quantum statistics (such as the Pauli exclusion principle) become negligible, and the Fermi-Dirac distribution simplifies to the classical Maxwell-Boltzmann distribution. This is because, at high temperatures, the energy levels are populated in a way that approximates classical behavior.

Hence, option (C) is correct.

12. Solution: (B)

$$\text{Planck's constant } (h) = 6.626 \times 10^{-34} \text{ J s}$$

$$\text{Mass of oxygen molecule } (m) = 5.31 \times 10^{-26} \text{ kg}$$

$$\text{Boltzmann constant } (k) = 1.38 \times 10^{-23} \text{ J K}^{-1}$$

$$\text{Temperature } (T) = 300 \text{ K}$$

$$\lambda = \frac{h}{\sqrt{2\pi m k T}}$$

Hence, option (B) is correct.

KARNATAKA SET

1. Solution: (A)

$$\text{Total number of particles} = n_0 + n_1 + n_2 + \dots$$

$$\left[N = \sum_{i=0}^{\infty} n_i = \sum_{i=0}^{\infty} g_i e^{-E_i/kT} \right]$$

Partition function

$$\left[q = \sum g_i e^{-E_i/kT} \right]$$

- # Partition function indicates how the particles are distributed between various energy levels
- # Partition function is an indication of the number of thermally accessible states at the temperature of interest.

Hence, option (A) is correct.

2. Solution: (C)

Same as Solution 14, Hence, option (C) is correct.

3. Solution: (D)

Heat capacity

(1) Heat capacity at constant volume $[C_V]$

$$C_V = \left(\frac{dU}{dT} \right)_V = \left(\frac{d}{dT} \left(NkT^2 \left(\frac{d \ln q}{dT} \right)_V \right) \right)_V$$

(2) At constant pressure $[C_P]$

$$C_P - C_V = nR$$

$$C_P = C_V + R$$

$$C_P = R + \left[\frac{d}{dT} \left(NkT^2 \left(\frac{d \ln q}{dT} \right)_V \right) \right]_V$$

(3) Entropy $S = k \ln W$

$$(i) \text{ Indistinguishable. } W = \pi \left(\frac{g_i}{n_i!} \right)^{n_i}$$

$$\boxed{S = Nk \ln \frac{q}{N} + \frac{U}{T} + Nk}$$

$$(ii) \text{ Distinguishable } W = N! \pi \left(\frac{g_i}{n_i!} \right)^{n_i}$$

$$S = Nk \ln q + \frac{U}{T}$$

So though a constant shift of energy levels of a system changes the partition function, Entropy and heat capacity do not change.

Hence, option (D) is correct.

4. Solution: (A)

Correct Match is

(i) molecular partition function $\rightarrow$ (b) $q = \sum g_i e^{-BE_i}$

(ii) Arrhenius equation $\rightarrow$ (c) $k = Ae^{-E_a/RT}$

(iii) Boltzmann constant $\rightarrow$ (d) $K_B = \frac{R}{N_A}$

(iv) Principle of detailed balance $\rightarrow$ (a) $K_C = \frac{K_1}{K_{-1}}$

Correct match is (i) - (b), (ii) - (c), (iii) - (d), (iv) - (a)

Hence, option (A) is correct.

5. Solution: (B)

$$q_{trans} = \frac{(2\pi m K_B T)^{3/2} \cdot V}{h^3}$$

At same temperature and same volume q_{trans} depends on molar mass

$$q_{trans} \propto (m)^{3/2}$$

$$\frac{q_{trans}(D_2)}{q_{trans}(H_2)} = \left(\frac{4}{2}\right)^{1.5}$$

$$\frac{q_{trans}(D_2)}{q_{trans}(H_2)} = (2)^{1.5} = 2.83$$

Hence, option (B) is correct.

6. Solution: (B)

Boltzmann distribution law :-

$$[n_i = g_i e^{-E_i/k_B T}]$$

$$K_B = \frac{R}{N_A}$$

$$\text{For 1 mole } [n_i = g_i e^{-E_i/RT}]$$

$$\text{Given } N_i = N e^{-BE_i}$$

$$g_i = N$$

$$+ \frac{E_i}{RT} = +B E_i$$

$$\boxed{\frac{1}{RT} = \beta}$$

Hence, option (B) is correct.

MAHARASHTRA SET

1. Solution: (B)

Incorrect statement

A system adiabatically coupled to a heat bath can be represented by a canonical ensemble. In Adiabatic process heat is constant. So statement (ii) is incorrect.

Hence, option (B) is correct.

2. Solution: (B)

$$Q = q^N$$

Q = total partition function

q = molecular partition function

N = Number of particles/molecules

For 1 mole = N_A number of particles.

$$Q_{trans} = q^{N_A} \rightarrow (i)$$

For distinguishable particles

$$Q_{trans} = \frac{q^{N_A}}{N_A!} \rightarrow (ii)$$

For Indistinguishable

divide (i) by (ii)

$$\frac{Q_{trans} (distinct)}{Q_{trans} (Indistinct)} = \frac{q^{N_A}}{q^{N_A}/N_A!}$$

$$\left[\frac{Q_{trans} (distinct)}{Q_{trans} (Indistinct)} = N_A! \right]$$

Hence, option (B) is correct.

3. Solution: (D)

$$q_{rot} = \frac{8\pi^2 I k T}{h^2}$$

$$\theta_{rot} = \frac{h^2}{8\pi^2 I K}$$

$$q_{rot} = \frac{T}{\theta_{rot}}$$

θ_{rot} = Rotational temperature.

$q_{rotational}$ = Rotational partition function.

$$\frac{q_{rot} (HCl)}{q_{rot} (HF)} = \frac{\theta_{rot} (HF)}{\theta_{rot} (HCl)} = \frac{30.2K}{15.2K}$$

$$\frac{q_{rot} (HCl)}{q_{rot} (HF)} = 1.98684 \approx 2$$

Hence, option (D) is correct.

4. Solution: (B)

$$\left[q_{trans} = \frac{(2\pi m k T)^{1.5}}{h^3} \times V \right]$$

For same molecular and same no. and volume

$$[q_{trans} \propto T^{1.5}]$$

$$\frac{q_{trans} (300K)}{q_{trans} (600K)} = \left(\frac{300}{600}\right)^{3/2} = \left(\frac{1}{2}\right)^{3/2} = \frac{1}{2^{3/2}}$$

$$\text{So } [q_{trans} (300K) : q_{trans} (600K) = 1 : 2^{3/2}]$$

Hence, option (B) is correct.

5. Solution: (D)

$$[q = \sum g_i e^{-E_i/RT}]$$

Given three states and degeneracy and energy

$$q = 1 e^0 + 4 e^{-E/kT} + 4 e^{-2E/kT}$$

At high temperature.

$$q = 1 + 4 e^{-E/\infty} + 4 e^{-2E/\infty}$$

$$\left[e^{\frac{1}{\infty}} = e^0 = 1 \right]$$

$$q = 1 + 4 + 4 = 9$$

for option (d) $(1 + 2e^{-\epsilon})^2 = 1 + 4e^{-2E} + 4e^{-E} = 9$ at high temperature

Hence, option (D) is correct.

6. Solution: (B)

$$q_{rot} = \frac{8\pi^2 IKT}{\sigma h^2}$$

q_{rot} = rotational partition function

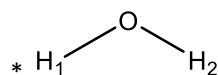
σ = Symmetry number

Symmetry number = indistinguishability factor

ex:- For $H_2 \rightarrow \sigma = 2$

* Homo diatomic molecule (e.g. H_2, O_2, N_2) = $\sigma = 2$

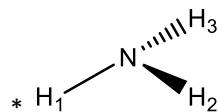
* Hetero diatomic molecule (e.g. HCl, CO, NO) = $\sigma = 1$



axis of rotation

C_2 -axis

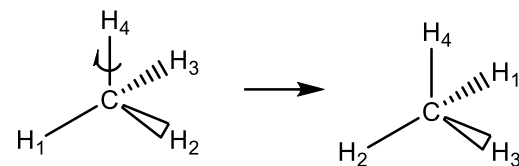
$$\boxed{\sigma = 2}$$



C_3

$$\boxed{\sigma = 3}$$

*



So from $H_4 \rightarrow 3$

$$H_1 \rightarrow 3$$

$$H_2 \rightarrow 3$$

$$H_3 \rightarrow 3$$

$$\Rightarrow 4 \times 3 = 12$$

$$\text{So } \boxed{\sigma = 12}$$

Symmetry number for methane is 12

Hence, option (B) is correct.

7. Solution: (A)

Given Statement

It is an open system

At constant temperature, Volume and chemical potential.

we know for Grand Canonical Ensemble μ, V, T are constant.

Hence, option (A) is correct.

8. Solution: (C)

N_j = No. of particle at j^{th} level.

$$N_j = \frac{g_j}{\exp\left(\frac{E_j - \mu}{k_B T}\right)} \rightarrow \text{(ii)}$$

Maxwell Boltzmann

$$N_j = \frac{g_j}{\exp\left(\frac{E_j - \mu}{k_B T}\right) - 1} \rightarrow \text{(iii)}$$

for Base Einstein

$$N_j = \frac{g_j}{\exp\left(\frac{E_j - \mu}{k_B T}\right) + 1} \rightarrow \text{(iv)}$$

For Fermi Dirac

g_j = degeneracy of j^{th} level.

$$\text{Given } \left[N_j = \frac{g_j}{\exp\left(\frac{E_j - \mu}{k_B T}\right) + a'} \right] \rightarrow \text{(i)}$$

If we compare (i) with (ii), (iii) and (iv)

$a = 0$ for Maxwell Boltzmann statistics

$a = 1$ for Fermi Dirac statistics

$a = -1$ for Base Einstein Statistics

$a = +1$ for fermi-Dirac Statistics.

Hence, option (C) is correct.

9. Solution: (D)

In Grand Canonical Ensemble

* It is an open system

* Chemical Potential, Volume and temperature are Constant. (μ, V, T Constant)

Here energy and Number of particles are not constant

So X can exchange both energy and particles with Y

Hence, option (D) is correct.

10. Solution: (A)

Canonical ensemble: - it is a closed system number of particles, volume and temperature are constant here.

So only energy can be exchange

X can exchange only energy with Y

Hence, option (A) is correct.

11. Solution: (C)

Fermi - Dirac statistics makes the following assumptions:- none of the states of the particles can hold more than one particle, exchanging a particle for another similar particle will not lead to a new state but will give same state known as identical particles.

So assumptions are particles are indistinguishable and only one particle may occupy a given energy level.

Hence, option (C) is correct.

12. Solution: (D)

The partition function is:

$$q = \sum_i g_i e^{-\frac{E_i}{kT}}$$

$$q = g_1 e^{-E_1/kT} + g_2 e^{-E_2/kT}$$